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COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF INTERNAL AFFAIRS

FUEL COMPETITION IN PENNSYLVANIA'S ELECTRIC GENERATING INDUSTRY

By

George F. Deasy

and

Phyllis R. Griess

TOPOGRAPHIC AND GEOLOGIC SURVEY

BULLETIN M 44

1961

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PENNSYLVANIA
GEOLOGICAL SURVEY
Fourth Series
BULLETIN M 44

FUEL COMPETITION IN PENNSYLVANIA'S ELECTRIC GENERATING INDUSTRY

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DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, Secretary
TOPOGRAPHIC AND GEOLOGIC SURVEY
Carlyle Gray, State Geologist
1961

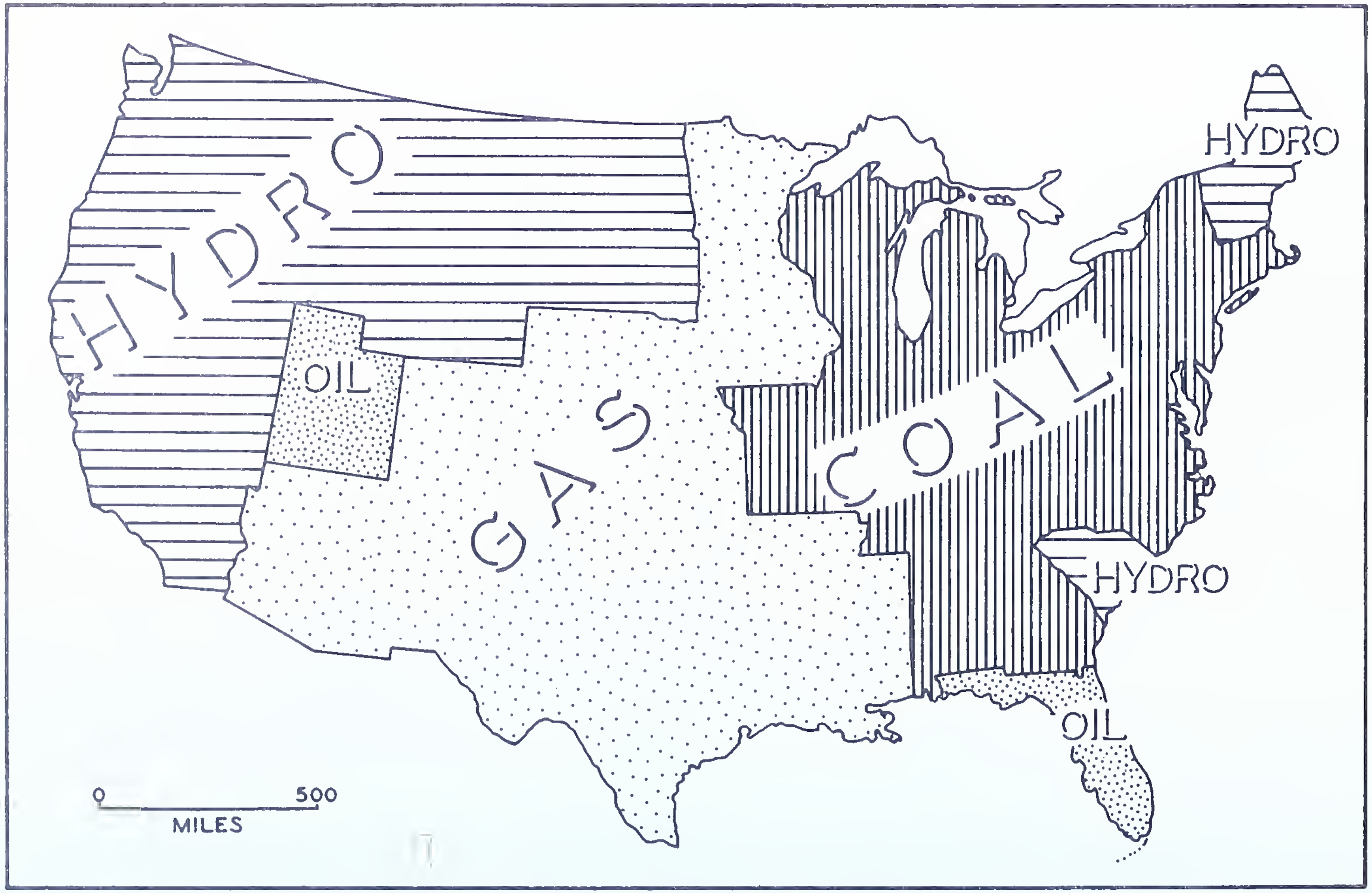
FOREWORD

This booklet describes the consumption of fuels in the electric generating industry of Pennsylvania and the factors affecting the selective use of the different fuels supplied both by in-state and out-of-state sources.

We are happy to publish this study which was done under the Mineral Conservation Section program of the College of Mineral Industries at The Pennsylvania State University. The authors are both professors in the Department of Geography at The Pennsylvania State University.

Genevieve Blatt

Genevieve Blatt
Secretary of Internal Affairs



Frontispiece. Major Sources of Primary Energy for Electric Generation in the United States, by States, 1957. Only the most important energy source is indicated for each state. Includes only electricity generated by utilities. Source: Federal Power Commission.

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FUEL COMPETITION IN PENNSYLVANIA'S ELECTRIC GENERATING INDUSTRY[1]

by

George F. Deasy and Phyllis R. Griess

ABSTRACT

A major market for Pennsylvania mineral fuels producers is the Commonwealth's electric generating industry, but competition among in-state and out-of-state fuels producers for this market is severe. Data relative to primary energy employed at 174 of the State's electric generating plants reveal significant geographical differences in types and sources of energy utilized. Resource proximity and transportation facilities account for most such differences; and these factors, when reduced to a monetary basis, indicate that selection of an energy type or source for use at a specific generating plant is largely determined by comparative delivered costs per unit of energy. Several courses of action are open to Pennsylvania's bituminous coal and anthracite producers which may enable them to expand their market territory and increase their share of the Commonwealth's electric generating industry fuel market.

INTRODUCTION

One of the major problems facing Pennsylvania mineral fuels producers is finding markets for their products. This is especially the case for coal producers, since productive capacity in both the bituminous and anthracite phases of the industry for years has exceeded consumption.

Among the more significant markets for fuels in Pennsylvania is the Commonwealth's electric generating industry. The competition in this market, however, is perhaps the most complex in the country, because all five major types of primary energy for the generation of electricity—bituminous coal, anthracite, petroleum, natural gas, and water power—are produced in significant quantities within the State. In addition, out-of-state sources of bituminous coal, fuel oil, and natural gas compete actively for a share of the market.[2]

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[1] Contribution No. 58-116 from the College of Mineral Industries, The Pennsylvania State University.

[2] Data utilized in this study are for the year 1956, and therefore predate initial development of commercially generated atomic power at Shippingport, Pa. in December, 1957.

This study analyzes regional differences in fuel types and sources employed in Pennsylvania's electric generating industry. Further, it examines the factors that are instrumental in the development of the energy patterns that presently exist. Such a study should prove of value to the mineral fuels producers of the Commonwealth, for it not only reveals the nature and extent of intrastate and interstate competition but it also suggests steps that may be taken to improve the competitive market position of the various types of Pennsylvania fuel producers.

ELECTRIC GENERATING FACILITIES IN PENNSYLVANIA

There are approximately 246 electric generating plants in Pennsylvania. Data of greater or lesser comprehensiveness on energy types and sources employed are available to the authors for 174 of these plants, which include almost all of the larger generating facilities and account for an estimated 97 per cent of the total generating capacity in the State.

The map in Figure 1 represents the approximate location of, and

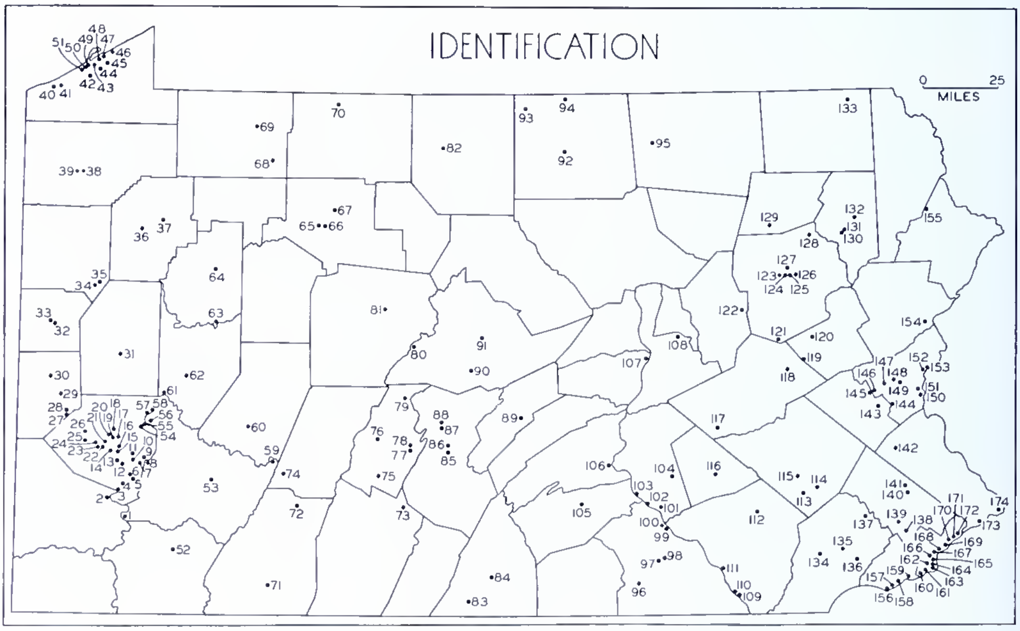

Fig. 1. Location and Identification of Electric Generating Plants in Pennsylvania Utilized in This Study, 1956. Refer to the Appendix for the key to plant numbers. Locations of plants in congested areas are only approximately correct. Source: personal communications.

identifies by number, the 174 generating plants utilized in this study. Names of the plant owners, and names and locations of individual plants, are given in the Appendix, and these data are keyed to Figure 1 to serve as a reference source to permit identification and specific location of plants shown on subsequent maps. In terms of this study the widespread distribution of generating facilities shown on Figure 1 is of prime importance, for statistical sites employed in construction of isolines and regional boundaries on succeeding maps thus are available for most parts of the State.

Another map, Figure 2, is introduced primarily as background material to round out the picture of Pennsylvania's electric generating facilities. It represents name-plate capacities, in megawatts, of the 174 plants considered in this study. Most of the plants are assigned, on a geographical basis, to one of two main divisions—Western and Eastern. Each division, in turn, contains a number of "groups" of plants, a group representing a local concentration of generating facilities. It should be emphasized that in subsequent pages the important consideration is not how much power can be generated at given localities, but instead the type (s) and source (s) of fuel employed at those localities.

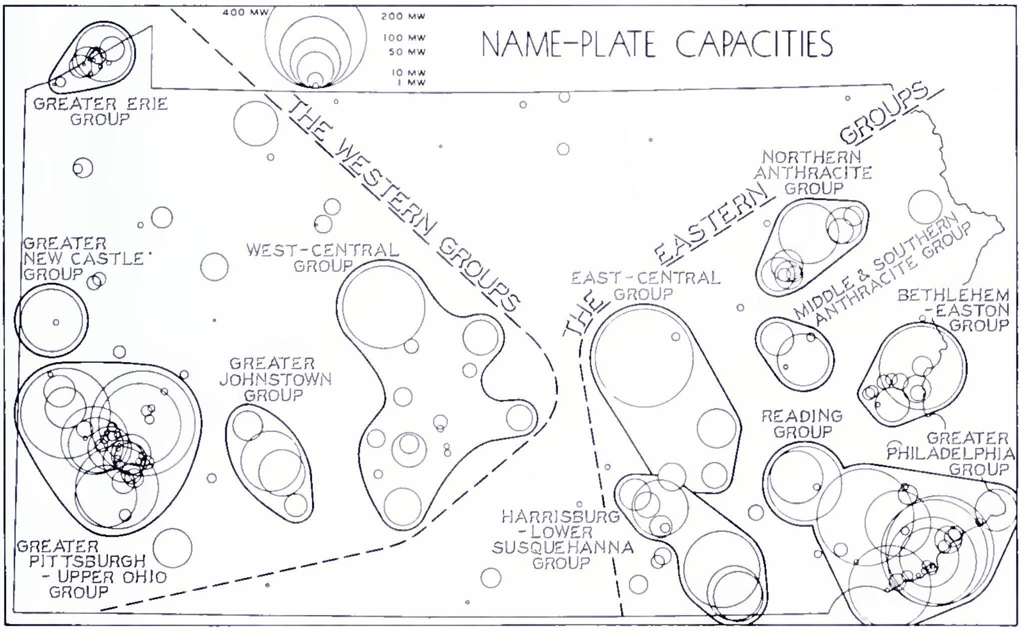

Fig. 2. Name-Plate Capacities, and Groupings, of Electric Generating Plants in Pennsylvania Utilized in This Study, 1956. The abbreviation "MW" refers to megawatts, one million watts. Source: personal communications.

TYPES OF PRIMARY ENERGY EMPLOYED IN ELECTRIC GENERATION

Data concerning primary energy types utilized at each of 170 electric generating plants in Pennsylvania are plotted on Figure 3. On the basis of such data, the State is divided into 9 type-of-energy zones and 6 type-of-energy nodes.

The Bituminous Coal Zone, as one might expect, covers much of, and extends to the four borders of, the Commonwealth. All 78 generating plants utilize bituminous coal only.

Next in importance, in terms of area covered, is the Anthracite Coal Zone, which comprises territory having generating plants employing only anthracite coal. This zone is located in the east-central part of the State and contains 19 plants.

Intermediate in position between the above two zones is a region

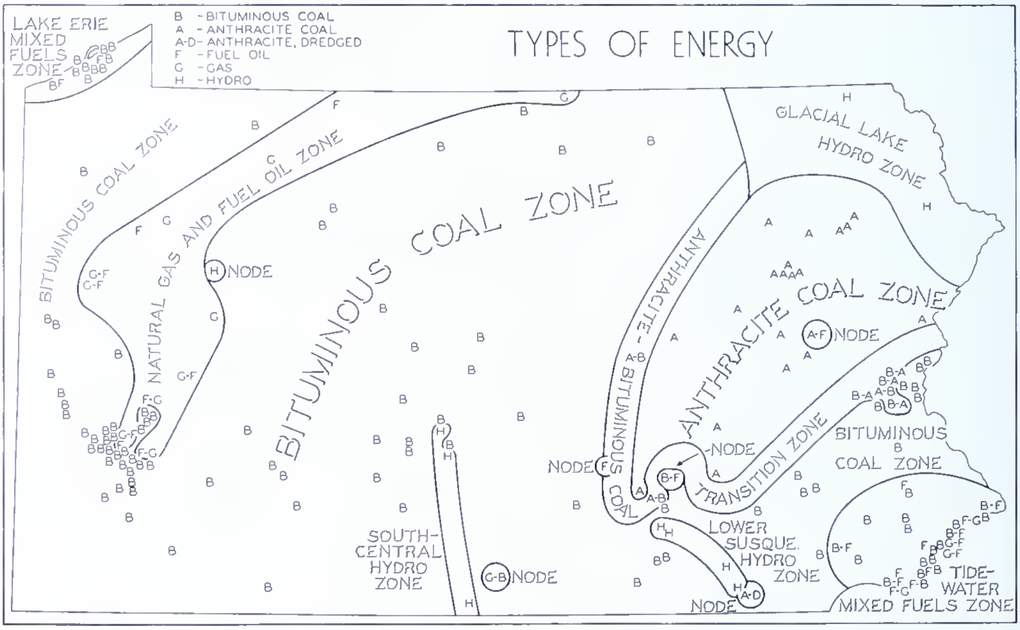

Fig. 3. Types of Primary Energy Employed at Selected Electric Generating Plants in Pennsylvania, 1956. In some plants, the form in which the primary type of energy is utilized differs from the original form. For example, 14 iron and steel plants (see Appendix) generate part of their electric energy from coal-derived coke, coke breeze, coke oven gas, and/or blast furnace gas. Seven cement plants (see Appendix) utilize coal-derived kiln gases and burning clinker to produce a percentage of their power requirements; and the gas used to generate part of the power at three oil refineries in the Greater Philadelphia area (see Appendix) largely is petroleum-derived refinery fuel gas. A minor amount (less than 5 per cent) of total power generated at many plants is accounted for by energy sources not indicated. Source: personal communications.

of mixed fuel types, the Anthracite-Bituminous Coal Transition Zone, in which are located electric plants burning both coal varieties. This narrow, belt-like zone is represented in both its western and southern parts by single plants (#107 and #102 on Figure 1 and in the Appendix), and in the east by one cluster of only five plants (#144 through #148); but it is presumed to be continuous in extent and to almost circumscribe the anthracite core area.

The Natural Gas and Fuel Oil Zone is located in the northwestern part of the State. Within it, 13 generating plants burn either gas or fuel oil, or both fuels. The Tidewater Mixed Fuels Zone, which includes 26 plants in Philadelphia and adjacent territory, is a region of competition between predominating bituminous coal on the one hand and fuel oil and gas, or a combination of the two, on the other hand. An analogous competitive fuels situation is found in the Lake Erie Mixed Fuels Zone in the northwestern corner of the State, although none of the 12 plants here uses gas. There are three separate zones depending upon falling water as a primary type of energy: the Glacial Lake Hydro Zone of the northeast (2 plants), the Lower Susquehanna Hydro Zone of the southeast (4 plants), and the South-Central Hydro Zone (3 plants) whose position is indicated by its name.

In addition to the nine primary energy zones enumerated above, Figure 3 designates six separate energy nodes. Each such node includes a single generating plant which employs an energy type different from that of neighboring plants. Thus, there is a hydro node in the west-central part of the State; a gas-bituminous coal node in the south-central part of the State; and four nodes in the east employing respectively, from west to east, fuel oil, bituminous coal-fuel oil, dredged anthracite, and anthracite-fuel oil.

In summary, then, one can see that the simple fuel type situation that presumably should exist in one of the nation's major coal producing states in reality resolves itself into a complex pattern of fuel competition. Different individual fuel types dominate various regions, and combinations of several fuel types characterize other areas.

SOURCES OF PRIMARY ENERGY EMPLOYED IN ELECTRIC GENERATION

The energy pattern for Pennsylvania's electric generating industry is further complicated by the fact that out-of-state sources supply appreciable quantities of energy that compete directly with Commonwealth sources. (This study is concerned only with energy entering Pennsylvania in its primary form; no account is taken of interstate movements of energy in the form of electricity.) Bituminous coal from West Virginia, and to a lesser extent from Ohio, finds an important market among Pennsylvania's electric plants; fuel oil from Mid-Continent, Gulf Coast, and foreign sources obtains an outlet in the State's generating industry; and natural gas, as well as petroleum-derived refinery fuel gas, from out-of-state sources offers competition to local energy suppliers (Griess and Deasy, 1960). The purpose of this section of the study is to point out the facts concerning regional differences in the fuel source situation.

Sources of Bituminous Coal. Information collected by the authors on sources of bituminous coal utilized at 103 electric generating plants in Pennsylvania employing this type of fuel, either alone or in combination with other fuel types, is plotted in Figure 4. The diversity of bituminous coal sources is demonstrated by the fact that 63 plants burn Pennsylvania bituminous coal exclusively, 20 plants use only West Virginia bituminous coal, three plants depend entirely upon Ohio bituminous coal, 16 plants employ a combination of Pennsylvania and West Virginia coal, and one plant uses a mixture of Ohio, West Virginia, and Pennsylvania coal.

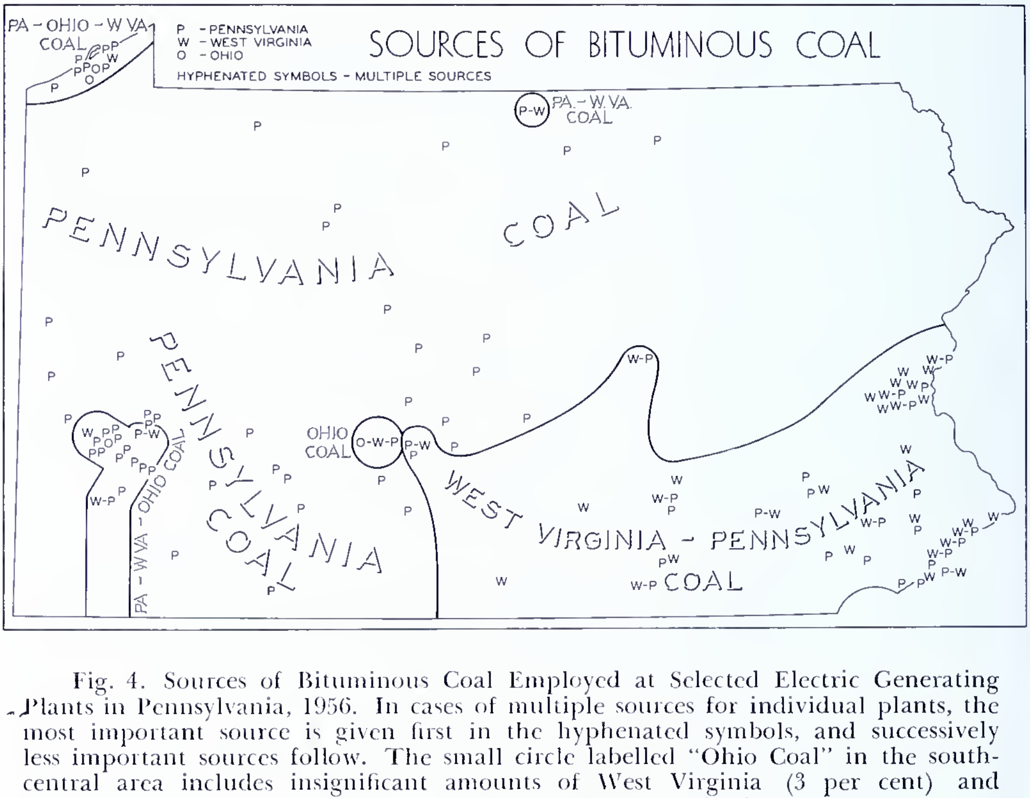

Fig. 4. Sources of Bituminous Coal Employed at Selected Electric Generating Plants in Pennsylvania, 1956. In cases of multiple sources for individual plants, the most important source is given first in the hyphenated symbols, and successively less important sources follow. The small circle labelled "Ohio Coal" in the south-central area includes insignificant amounts of West Virginia (3 per cent) and Pennsylvania (2 per cent) coal. Source: personal communications.

More important than a mere tabulation of heterogeneous sources, however, is the graphic evidence in Figure 4 that there exist concentrations of bituminous coal from out-of-state sources in certain restricted territories of the Commonwealth, whereas elsewhere no West Virginia or Ohio coal is used. There is a sizeable area in southeastern and south-central Pennsylvania comprising approximately one-fifth of the State, for instance, in which large amounts of West Virginia coal are burned either alone or in combination with Pennsylvania bituminous or anthracite coal. Of special importance as markets for West Virginia coal in this area are: (1) a number of large capacity stations of the Philadelphia Electric Company (#137, #139, #165, #167, #168) in the Greater Philadelphia area; (2) many of the cement manufacturing plants (#145 through #150, and #153), as well as the Bethlehem Plant of the Bethlehem Steel Company (#144) and the Martins Creek Station of the Pennsylvania Power and Light Company (#152), in the Bethlehem-Easton area; and (3) the large Sunbury Station of the Pennsylvania Power and Light Company (#107).

Moreover, there is a small area in the northwest, extending along the Lake Erie shore, in which Pennsylvania coal faces competition not only from West Virginia coal but also from that of Ohio. The two plants utilizing Ohio coal are #42 and #43; the one plant employing West Virginia coal is #45. All three are small manufacturing concerns.

A third area in which out-of-state bituminous coal is utilized is in the southwest, where generating plants near the junction of the Ohio, Allegheny, and Monongahela rivers burn West Virginia and Ohio coal as well as that from Pennsylvania. The plant using 100 per cent West Virginia coal is that of a coke and chemical company (#26); the two plants employing both West Virginia and Pennsylvania coal are large private utility stations (#2 and #54); and the plant depending entirely upon Ohio coal is the Pittsburgh Station power plant of the Pennsylvania Railroad Company (#21).

Finally, two minor nodes in which out-of-state coal is used are found in the north-central and south-central parts of the Commonwealth. The north-central plant belongs to a small tanning company (#93); it employs 92 per cent Pennsylvania coal and 8 per cent West Virginia coal. The south-central plant is part of the Altoona Works of the Pennsylvania Railroad Company (#76) and uses 95 per cent Ohio coal, 3 per cent West Virginia coal, and 2 per cent Pennsylvania coal.

Elsewhere throughout the State, wherever bituminous coal is employed in the generation of electricity, its source is entirely from mines within the State. Note that nowhere in Pennsylvania, even within areas purchasing West Virginia and Ohio coal, is local coal entirely displaced by the out-of-state product. Presumably price and/or quality differentials between coals from the several sources are relatively so small, in areas of competition, that the several sources can effectively compete with each other for the market.

Sources of Fuel Oil and Gas. The competitive situation with regard to sources of fuel oil is shown in Figure 5, which indicates fuel source information for 15 of the 27 electric generating plants in Pennsylvania employing oil alone or in combination with another energy type. It is apparent that out-of-state fuel oil is used exclusively by oil-burning plants in the Greater Philadelphia area of the southeast (#135, #141, #158, #169, #170, #172), the Greater Erie area of the northwest (#41), the Greater Pittsburgh area of the southwest (#9, #62), and at three plants in the eastern interior of the State (#104, #106, #120). Only in the interior northwest are there generating plants employing Pennsylvania-derived crude (#35, #36, #70).

The gas source situation (Fig. 6) is somewhat similar to that for fuel oil. Gas from out-of-state sources is employed exclusively in the three gas-using electric generating plants of the Greater Philadelphia area for

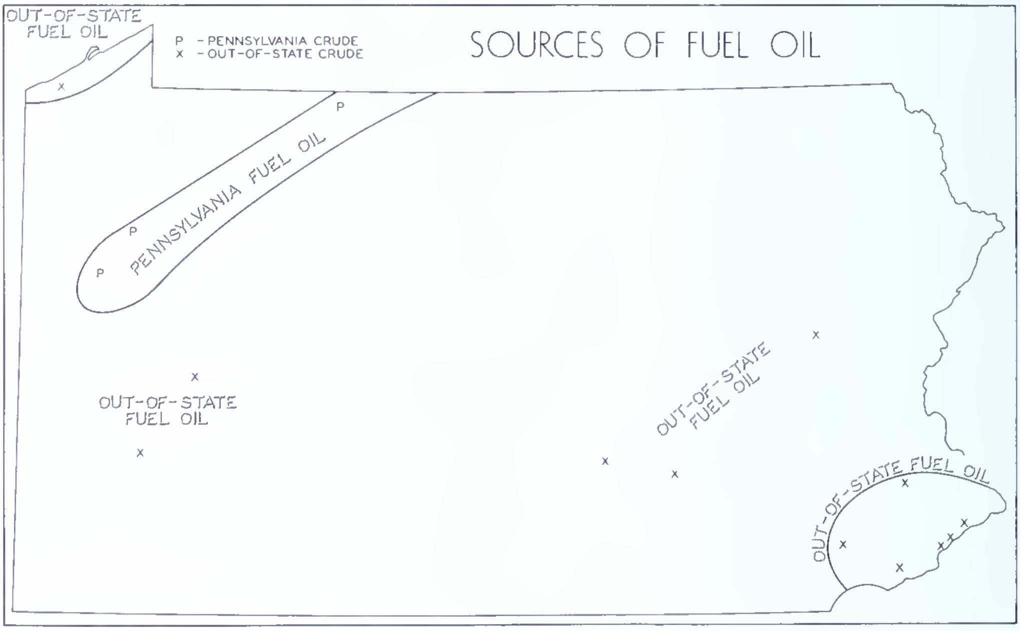

Fig. 5. Sources of Fuel Oil Employed at Selected Electric Generating Plants in Pennsylvania, 1956. Source: personal communications.

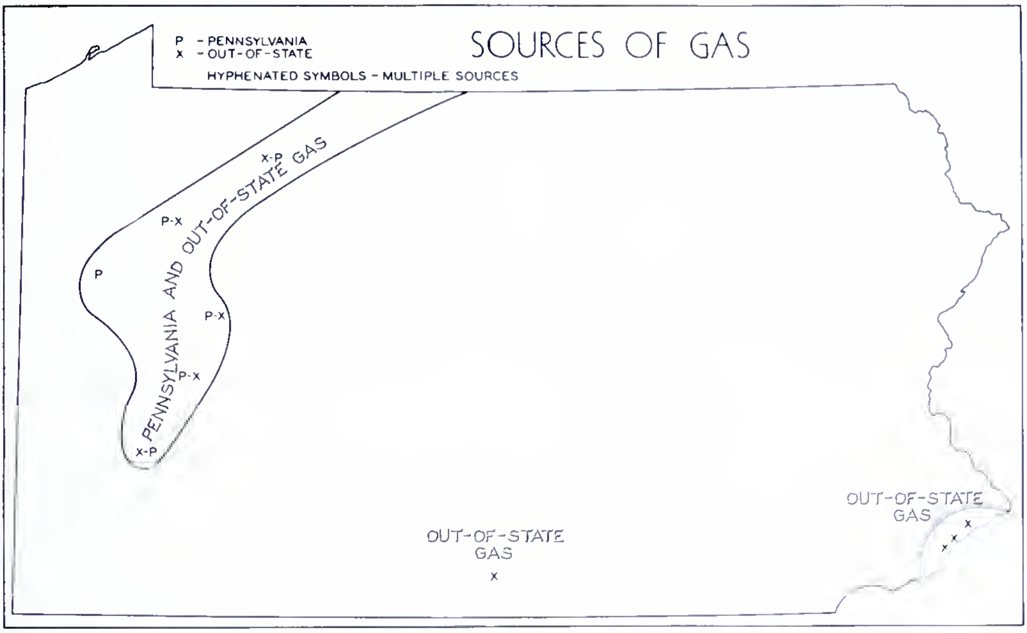

Fig. 6. Sources of Gas Employed at Selected Electric Generating Plants in Pennsylvania, 1956. Includes refinery fuel gas. Source: personal communications.

which source data are available (#169, #170, #172; part of this is refinery fuel gas obtained during the processing of crude petroleum), and in the one gas-using plant in the south-central part of the State (#84). On the other hand, the six plants in the Greater Pittsburgh area and the northwestern interior for which source data are available (#9, #35, #37, #62, #63, #68) all employ either Pennsylvania-derived gas or a combination of Pennsylvania and out-of-state gas.

Sources of Anthracite and Water Power. Unlike the situation with regard to previously treated energy types, there is no competition for Pennsylvania anthracite producers from out-of-state anthracite sources since no nearby area produces the fuel. Likewise, no out-of-state water is transported into the Commonwealth for purposes of generating electricity; hydro-generated energy enters only in the form of electricity.

Summarizing the energy source situation for electric generating plants in Pennsylvania, it is evident that the source pattern for the State is as complex as the energy type pattern. Both neighboring states and more distant areas furnish primary energy in appreciable quantities and of various types to a large number of generating plants within the Commonwealth, and offer active competition to State-derived energy.

FACTORS PRODUCING REGIONAL DIFFERENCES IN ENERGY TYPES AND SOURCES

The map in Figure 7 represents the major, and some of the minor, factors involved in the regionalization of energy types and sources used by the electric generating industry of Pennsylvania. It is evident, on examination of the map, that all such factors are concerned with the location and character of energy resources and of transportation facilities. No attempt is made here to evaluate quantitatively the significance of the individual factors, although the approximate importance of many is evident without quantification.

The mapped factors associated with in-state types and sources of energy are five in number. First there are the extensive deposits of bituminous coal in the western half of the Commonwealth, which represent a total or partial source of power for most generating plants situated on or in the vicinity of such deposits, as well as for certain plants of more distant location (compare Figs. 3 and 4 with Fig. 7). Then there are the more restricted deposits of anthracite in the east-central part of the State, which constitute a total or partial source of energy for most generating plants situated on or in the vicinity of the deposits (compare Fig. 3 with

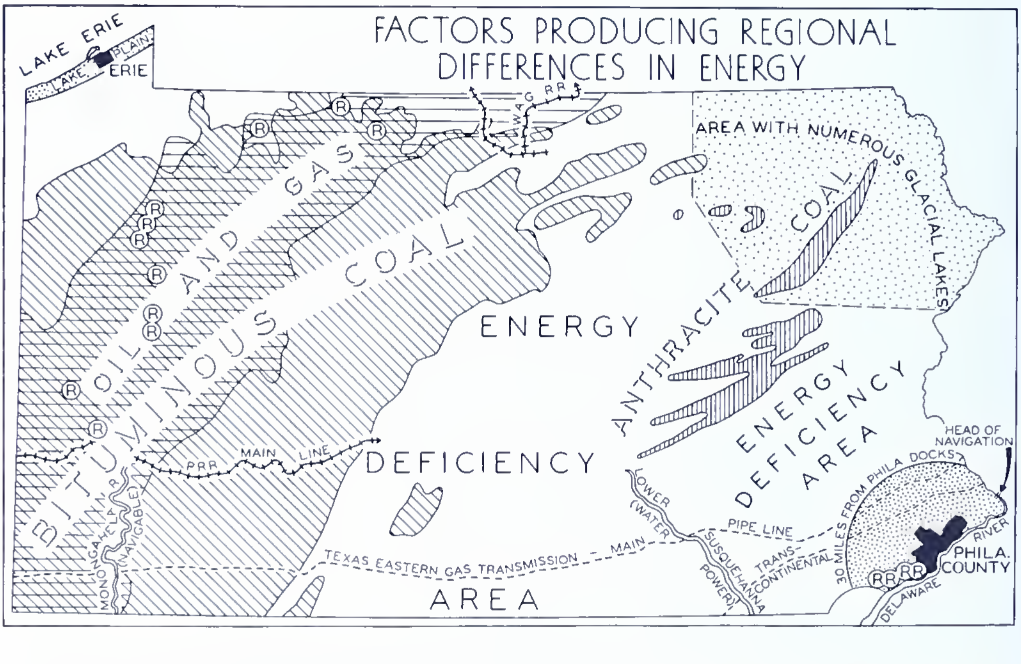

Fig. 7. Selected Factors Producing Regional Differences in Energy Types and Sources Utilized for Electric Generation in Pennsylvania, 1956. Boundaries of fuel regions are generalized. Each circled "R" represents a petroleum refinery. Sources: various.

Fig. 7). Other factors include the oil and gas producing area in the western part of the State, together with associated refineries (represented by circled "R"s on Fig. 7), which supplies all or part of the energy for a limited number of generating plants located mainly in the currently more productive northern portion of the field (compare Figs. 3, 5, and 6 with Fig. 7); the glacial lake area in the northeastern corner of the State, which supplies hydro power for two electric generating plants (compare Fig. 3 with Fig. 7); and, finally, the lower Susquehanna River in southeastern Pennsylvania which, with its large flow but navigation-hindering rapids, furnishes hydro power for four generating plants (compare Fig. 3 with Fig. 7).

Mapped factors associated with out-of-state types and sources of energy are eight in number. One such is the navigable lower Delaware River in southeastern Pennsylvania, which provides access via ocean tanker for out-of-state crude oil to Greater Philadelphia refineries (represented by circled "R"s on Fig. 7), and these in turn furnish fuel oil via highway tank truck for generating plants located within a 30-mile radius of the Philadelphia docks (compare Figs. 3 and 5 with Fig. 7). Another factor is the two largest natural gas pipe lines serving Pennsylvania, the Texas Eastern and Trans-Continental, which supply partial energy requirements for one generating plant in the south-central part of the State and for several others in the Greater Philadelphia area (compare Figs. 3 and 6 with Fig. 7). A third factor is the navigable lower Monongahela River and connecting navigable waters of the lower Allegheny and upper Ohio rivers, which enable barge-transported West Virginia bituminous coal to invade southwestern Pennsylvania's coal producing territory and provide partial or total energy for three generating plants located along those rivers (compare Fig. 4 with Fig. 7). A fourth and fifth factors are the main line of the Pennsylvania Railroad in the western part of the State, which enables Ohio coal to compete with Pennsylvania and West Virginia coal in the railroad's own two western Pennsylvania generating plants (compare Fig. 4 with Fig. 7); and the Wellsville, Addison, and Galeton Railroad in north-central Pennsylvania, which quotes no commodity freight rates for Pennsylvania bituminous coal but which will haul West Virginia coal to the lone generating plant in Pennsylvania located on its lines[3] (compare Fig. 4 with Fig. 7). Other factors localizing out-of-state energy sources in Pennsylvania include the narrow plain along

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[3] The following personal communication, dated Nov. 17, 1958 and addressed to the authors, was received from Mr. B. S. Niekras, purchasing agent for the Eberle Tanning Company of Westfield, Pa., the owner of the generating plant under consideration:

"Perhaps on the face of it, it seems odd that we should use coal both from the Pennsylvania and the West Virginia fields. There is an explanation for this. We the shores of Lake Erie which, compared to the hilly terrain of the Appalachian Plateau immediately south, is a topographically favored trunk line route for east-west railroads having good connections with Ohio and West Virginia coal fields, and which therefore permits several lake plain generating plants to employ out-of-state coal (compare Fig. 4 with Fig. 7); and the navigable waters of Lake Erie, together with the port facilities of the city of Erie, which provide access to the northwestern corner of Pennsylvania for lake-transported fuel oil and enable several lake plain generating plants to employ such fuel (compare Figs. 3 and 5 with Fig. 7). A final factor is the extensive energy-deficient territory in much of south-central and southeastern Pennsylvania, which comprises an area wherein out-of-state energy can most effectively compete with Pennsylvania sources (compare Figs. 4, 5, and 6 with Fig. 7).

Additional factors, none of major importance, which influence the regional pattern of energy types and sources in Pennsylvania are not shown on the map in Figure 7 because of cartographic limitations. Among these are the fuel oil and natural gas pipe lines in the Commonwealth, exclusive of the two major lines mentioned earlier, which supply energy from out-of-state sources to a limited number of small generating plants whose source of gas and oil has not already been stated (Figs. 5 and 6); the middle Susquehanna River and its east bank tributaries, which drain much of the anthracite area and provide dredgable coal fines for a large generating plant located downstream near the Maryland border (Figs. 3 and 7);[4] and several small hydro sites along minor streams in the energy-deficient area of south-central Pennsylvania, which sites have been developed because of lack of superior local energy facilities (compare Figs. 3 and 7).

Some of the broader implications of the above factors, both mapped and unmapped, in terms of regional differences in energy types and sources, are readily apparent to the reader. More explicit and compre-

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use a strip mine coal that is washed and screened and delivered to us via truck. During the winter months, in order to be assured of a continuity of fuel, we take a carload a week of rail coal, which we have been getting from the West Virginia fields. Our town has both New York Central and Wellsville, Addison, and Galeton Railroads. However, our plant is located on the WA&G Railroad and we must have WA&G Railroad delivery. If we were also located on the NYC Railroad, we could try other coals from the Pennsylvania coal fields. We have investigated and find no commodity freight rates from these fields and can bring in the West Virginia coal, therefore, at a satisfactory cost delivered for part of our requirements during the winter months."

[4] This is only one of several dredging operations conducted along the Susquehanna, Schuylkill, and Lehigh rivers and their tributaries, which drain the anthracite area. The Susquehanna accounts for about 90 per cent of the dredged coal. Much such coal is used for industrial purposes other than the generation of electricity.

hensive treatment of these factors, expressed in monetary terms, is included in the analysis of energy types and sources that follows.

ANALYSIS OF ENERGY TYPES AND SOURCES FOR ELECTRIC GENERATION

Pennsylvania Bituminous Coal

The most important element in the Pennsylvania electric energy picture unquestionably is the Commonwealth's own supply of bituminous coal. Such coal powers more generating plants and supplies electricity to a more extensive territory than any competing type or source of energy (Figs. 3 and 4). Nevertheless, as has previously been pointed out, this fuel by no means monopolizes the electric generating market of the State, and over extensive areas it is wholly or partially displaced by other types or sources of energy. Two questions may be raised in attempting to explain areal variations in use of Pennsylvania bituminous coal: (1) to what extent do delivered costs of this fuel vary geographically within the State, and (2) to what cause or causes may such geographical variations in delivered cost be attributed?

Cost Data and the Cost Pattern. Cost data submitted to the authors for 51 generating plants burning Pennsylvania bituminous coal for all or part of their energy requirements show that, on a per ton delivered basis, costs range from a low of $3.37 to a high of $10.02. Of the total plants tabulated, 14 obtain coal for $5.00 a ton or less, 11 pay from $5.01 to $6.00, 10 from $6.01 to $7.00, 6 from $7.01 to $8.00, 2 from $8.01 to $9.00, 7 from $9.01 to $10.00, and one pays more than $10.00. Such figures indicate that in general Pennsylvania bituminous coal is employed by fewer generating plants as its delivered cost increases.

The geographical pattern of delivered costs is shown in Figure 8, which indicates the per ton cost of coal at the 51 generating plants under consideration plus generalized probable cost isolines for the State as a whole. The main area of low cost coal (under $5.00 per ton) is found in a broad east-west belt extending from the center of the State to the middle of its western border. Costs increase progressively but at irregular rates outward from this low cost core area, to the north and south but especially to the east. Local interruptions to the general pattern are found, among other places, in the Greater Pittsburgh area of the southwest, where coal prices are anomalously high, and along the lower Monongahela River in the southwest, where coal prices are anomalously low.

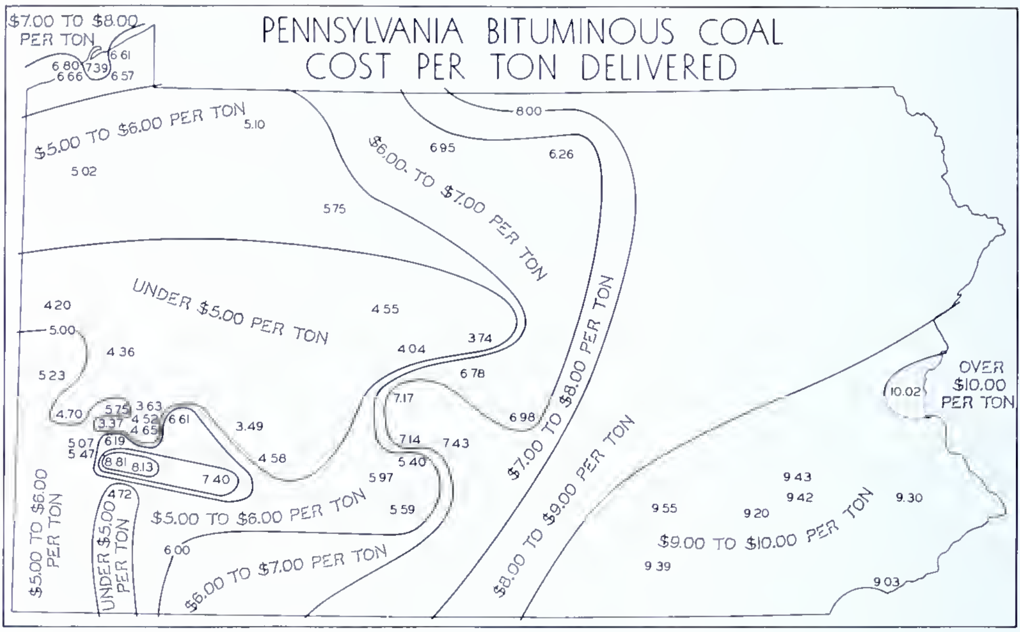

Fig. 8. Delivered Cost Per Ton of Pennsylvania Bituminous Coal Consumed at Selected Electric Generating Plants in Pennsylvania, 1956. Generalized probable cost isolines are also shown. This map is included because it expresses cost in terms of a unit (tons) that is familiar to most readers; Figure 9 is a more accurate representation of fuel costs, since it takes into account regional variations in the heat content of a ton of coal. Source: personal communications.

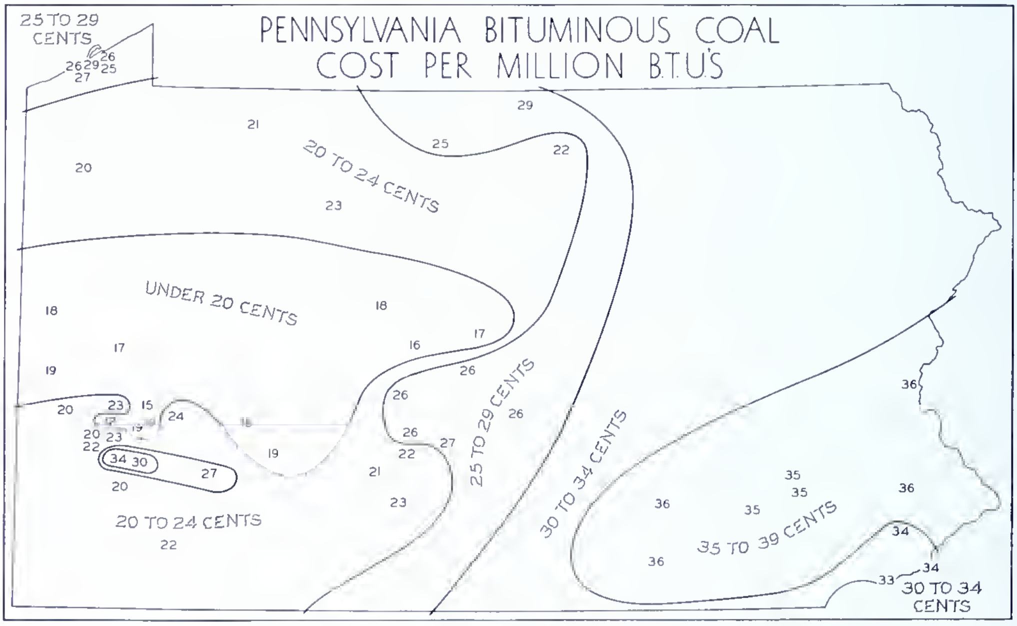

Fig. 9. Delivered Cost Per Million B.T.U.'s of Pennsylvania Bituminous Coal Consumed at Selected Electric Generating Plants in Pennsylvania, 1956. Figures are calculated to the nearest whole cent. Generalized probable cost isolines are also shown. Source: personal communications.

Pennsylvania bituminous coal is most expensive in the easternmost part of the State, being priced at over $10.00 a ton delivered in the vicinity of Easton.

A companion map to the above, and one more representative of actual energy costs, is that of Figure 9 which indicates delivered costs of Pennsylvania bituminous coal per million B.T.U.'s[5] at 52 generating plants plus generalized probable cost isolines for the State as a whole. The cost pattern on this map is slightly at variance with that on the preceding one, but main components of the original pattern remain. The second map will be the one generally referred to in subsequent pages, since it expresses cost information on a basis that permits comparison with cost data for other competing types and sources of fuel.

Explanation of the Cost Pattern. The delivered cost pattern of Pennsylvania bituminous coal is dependent upon the five components of such cost: (1) the B.T.U. content of the coal, (2) mining and processing expenses, (3) mining and processing profits, (4) delivery expenses, and (5) delivery profits. The average B.T.U. content of Pennsylvania bituminous coal differs appreciably from one part of the coal fields to another, and is closely related to the percentage of fixed carbon in the coal. (In general, the higher the fixed carbon, the higher the heat value per pound.) Figures range, on a county basis, from as low as 14,750 B.T.U.'s to as high as 15,750 B.T.U.'s per pound for dry and ash-free coals, and typically decrease from the southeastern to the northwestern portions of the coal fields (Ashley, 1928, p. 176-177). Mining and processing expenses also differ considerably from place to place within the bituminous coal fields of the State, and indeed from one mine to another within any given segment of the fields. Many factors enter into the mining and processing expense structure, including such items as whether mining is underground or strip, whether the scale of mining operations is large or small, whether or not mining personnel are unionized with consequent effects on wage rates, whether seams being mined are thick or thin and clean or dirty, whether (in strip mining) the overburden is great or small, whether (in underground mining) drift entry is possible or instead slope or shaft entry is necessary, and whether (in underground mining) the roof rock is strong or weak. Mining and processing profits differ, of course, from mine to mine on the basis of management's ability to obtain a favorable price for its product.

A synthesis of areal variations in the B.T.U. content of coal, mining and processing expenses, and mining and processing profits may be expressed in terms of areal differences in the F.O.B. mine value of coal per million B.T.U.'s. This figure ranges, on a county average basis, from as low as 11 cents to as high as 23 cents (Fig. 10). It is evident from Figure 10 that, with few exceptions, the southern tiers of bituminous coal mining counties are high cost producers (over 20 cents per million B.T.U.'s, F.O.B. mine),[6] whereas remaining coal mining counties farther north almost without exception are low cost producers (under 20 cents per million B.T.U.'s, F.O.B. mine). Thus it becomes obvious why the delivered cost of Pennsylvania bituminous coal is higher at generating plants in the southern tiers than it is in the middle tiers of counties (compare Figs. 9 and 10). What is surprising, in view of low F.O.B. mine values of coal in the northern tiers of mining counties, is the relatively high delivered costs in those counties (compare Figs. 9 and 10). This situation is due to the fact that almost all bituminous coal mines in the State (97 per cent), and an even higher percentage of total coal production, are located in the central and southern producing counties, within the "boundary of significant coal production" on Figure 10. Hence, even though mine values of coal are low to the north of this boundary, production sites are relatively so limited in number and so widely spaced that coal presumably must be shipped appreciable distances from mines to generating plants, thus raising delivered costs per million B.T.U.'s in the north.

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[5] Such data were furnished by the recipients of questionnaires, or were calculated by the authors on the basis of data supplied relative to average B.T.U.'s per pound of coal consumed and average cost per ton of coal consumed.

If one probes deeper into the subject of the cause or causes of areal variations in mine prices of Pennsylvania bituminous coal, the conclusion inevitably is reached that among all the factors involved the one of outstanding importance is the type of mining practiced—whether underground or strip. Where stripping is significant, coal is relatively cheap because tonnages mined per man/day are large; where deep mining prevails to the virtual exclusion of stripping, coal is relatively expensive because output per man/day is small. (The average production per man/day from Pennsylvania strip mines in 1953 was 12.79 tons; from underground mines, 5.88 tons.) Since stripping of bituminous coal today is concentrated largely in the middle and northern producing counties (Fig. 11), mine prices of coal are relatively low in those areas. Moreover, since large quantities of stripped coal in close proximity to generating plants can be had only in the middle tiers of producing counties (within the "boundary of significant coal production" on Figure 11), it is in

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[6] Delivered costs per million B.T.U.'s in the southern producing counties (Fig. 9) are in some cases slightly lower than average F.O.B. mine values given for those counties in Figure 10 because electric generating plants typically burn the cheaper grades of coal. Much high value metallurgical coal also comes from the southern counties.

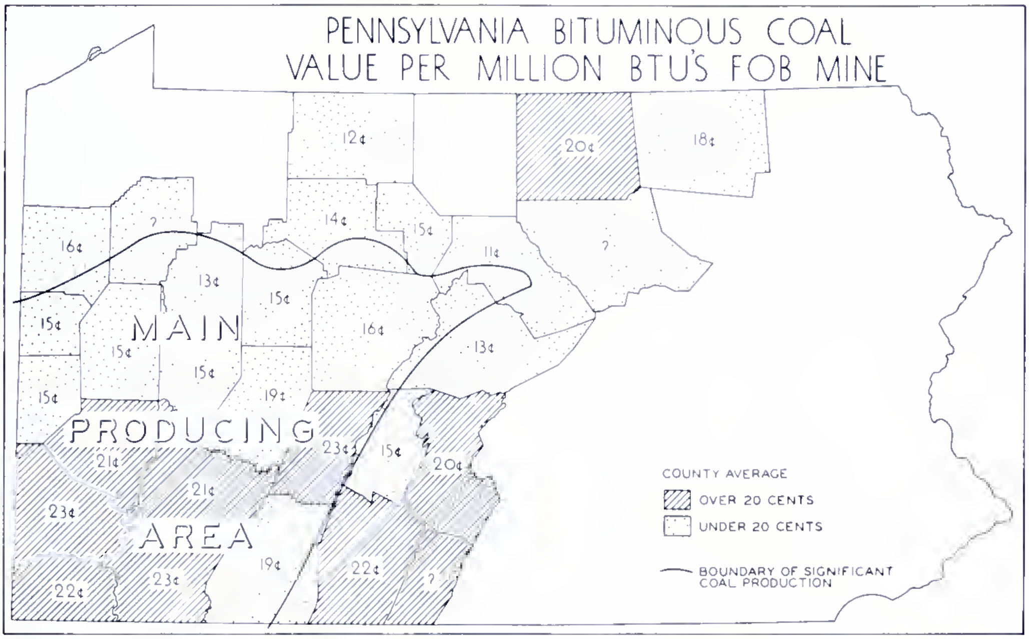

Fig. 10. Average F.O.B. Mine Value of Pennsylvania Bituminous Coal per Million B.T.U.'s, on a County Basis, 1953. Includes all grades of coal. All coal is assumed to have an average content of 3 per cent moisture and 9 per cent ash. Figures are calculated to the nearest whole cent. See text for explanation of "boundary of significant coal production." Sources: calculated from data in U. S. Bureau of Mines, 1953, p. 122-123 and Ashley, 1928, p. 177.

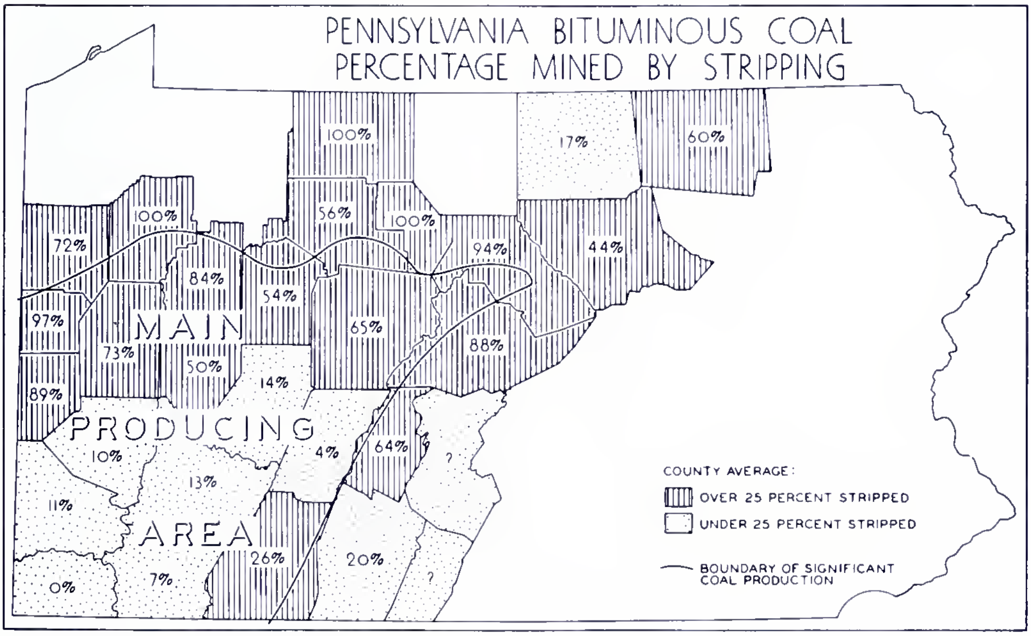

Fig. 11. Percentage of Pennsylvania Bituminous Coal Mined by Stripping, on a County Basis, 1952. Percentages refer to tonnage, not value. Source: U. S. Bureau of Mines, 1952, p. 83, 109.

these counties only that the delivered cost of coal at generating plants is low (under 20 cents per million B.T.U.'s on Figure 9).

Thus far attention has been primarily directed in this section of the study to the effects of variations in heat value, and mining and processing expenses and profits, on areal differences in delivered cost of Pennsylvania bituminous coal at Commonwealth generating plants. There remains for analysis the effect of delivery expenses and profits on areal differences in the delivered cost of such coal. Such expenses and profits may be approximated by comparing mine values of coal in the producing counties (Fig. 10) with delivered costs of coal at generating plants (Fig. 9).

Correspondence indicates that the bulk of Pennsylvania bituminous coal shipped to generating plants located outside the coal fields originates in the low-cost middle tiers of mining counties. Hence the value of coal at its presumed place of origin averages between 13 and 19 cents per million B.T.U.'s (Fig. 10). When received at the generating plant such coal costs up to 36 cents per million B.T.U.'s (Fig. 9), indicating delivery expenses and profits of as much as 23 cents per million B.T.U.'s. As is evident from the isolines on Figure 9, delivery expenses and profits are very roughly proportional to the distance between mining area and generating plant. However, as might be expected, isolines are close together immediately east and southeast of the main low-cost producing area whereas they are more widely spaced farther southeastward, thus conforming to the normal situation of steep expense gradients for short haul movement of goods and more gentle gradients for longer haul movements.

There are a number of interesting variations from the generalized delivery expense and profits situation described above, several of which previously were mentioned. In the Greater Pittsburgh area, for instance, delivered costs for Pennsylvania bituminous coal at generating plants rise as high as 34 cents per million B.T.U.'s (Fig. 9), presumably because of the increased expense of delivery in a congested and highly urbanized region. In contrast, the delivered cost of Pennsylvania bituminous coal is anomalously low at a generating plant located on the lower Monongahela River (best shown on Fig. 8, at $4.72 per ton), because it receives coal by barge from upstream mines situated along the river. The broad eastward bulge along the southern part of the 24 cent isoline on Figure 9 may be attributed to the existence of a disconnected outlier of coal-bearing strata that extends 30 miles to the east of the margin of the main coal territory (Fig. 7). The lower delivered cost of Pennsylvania bituminous coal at Greater Philadelphia generating plants, as compared with prices at plants located farther to the west (Fig. 9), probably is a result of irregularities in the coal freight rate structure of the area.

In summary, it can be seen that the delivered cost pattern for Pennsylvania bituminous coal employed by generating plants within the Commonwealth, as depicted in Figure 9, can be attributed to a number of factors. Delivered costs are lowest (under 20 cents per million B.T.U.'s) where generating plants are located in areas of large volume strip mining. Delivered costs are somewhat higher (20 to 24 cents) where generating plants are situated in areas of large volume underground mining or in areas of small volume strip mining. Delivered costs to generating plants increase rapidly (up to from 30 to 34 cents) within a short distance to the east and southeast of the above areas and then more gradually (up to 36 cents) with increasing distances southeastward, as fixed charges associated with rail transport are proportioned over a greater number of miles. Several minor variations from the above pattern may be attributed to local transport or mining conditions.

WEST VIRGINIA BITUMINOUS COAL

One of the apparently anomalous aspects of the primary energy facet of Pennsylvania's electric generating industry is the degree to which, and the areas in which, use is made of West Virginia bituminous coal (Fig. 4). Such coal supplies a major share of the southeastern and south-central Pennsylvania utility market, even though handicapped by a location 50 to 100 miles farther from this market than competing Pennsylvania produced bituminous coal. Moreover, West Virginia coal in limited amounts invades the Commonwealth's own bituminous coal mining territory in southwestern and north-central Pennsylvania, and approaches the margins of the coal fields in the northwest. In order to understand the ability of West Virginia coal to acquire a share of Pennsylvania's utility markets, the following steps are necessary: (1) delivered costs of West Virginia coal must be ascertained and compared with those of the equivalent Pennsylvania product in areas of competition, and (2) the factor or factors that determine the West Virginia coal cost pattern, and that make West Virginia delivered costs competitive, must be ascertained.

Cost Data and the Cost Pattern. Cost data in terms of dollars, available to the authors for 21 generating plants employing West Virginia coal for all or part of their energy requirements and located in southeastern and south-central Pennsylvania, plus probable cost isolines, are plotted in Figure 12. On a per ton delivered basis, costs range from as low as $8.14 to as high as $10.10; with 15 plants reporting costs of less than $9.00, 5 plants between $9.00 and $10.00, and one plant over $10.00.

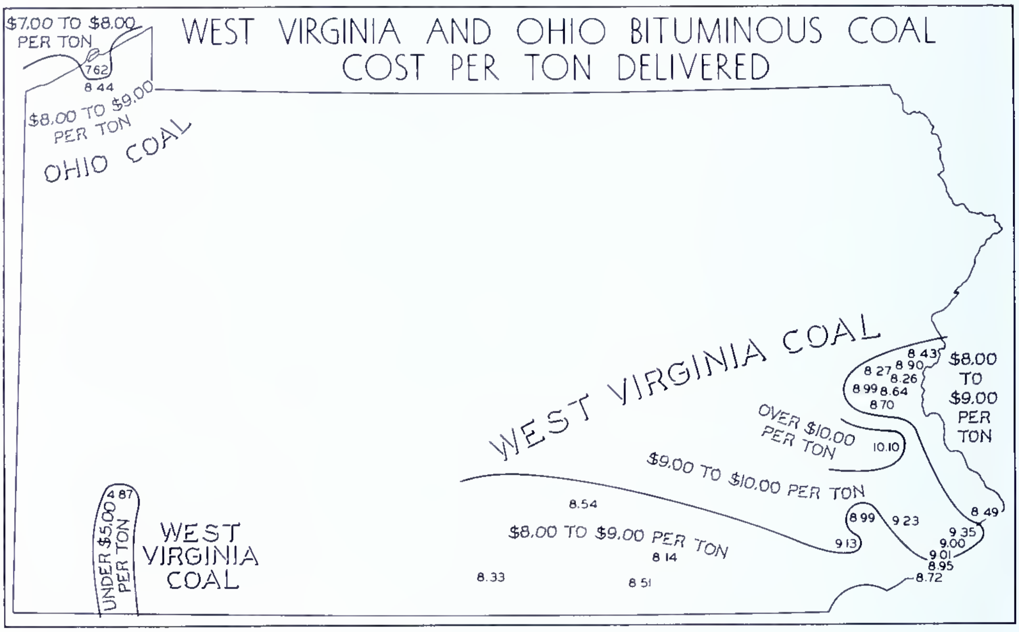

Fig. 12. Delivered Cost Per Ton of West Virginia and Ohio Bituminous Coal Consumed at Selected Electric Generating Plants in Pennsylvania, 1956. Generalized probable cost isolines are also shown. Source: personal communications.

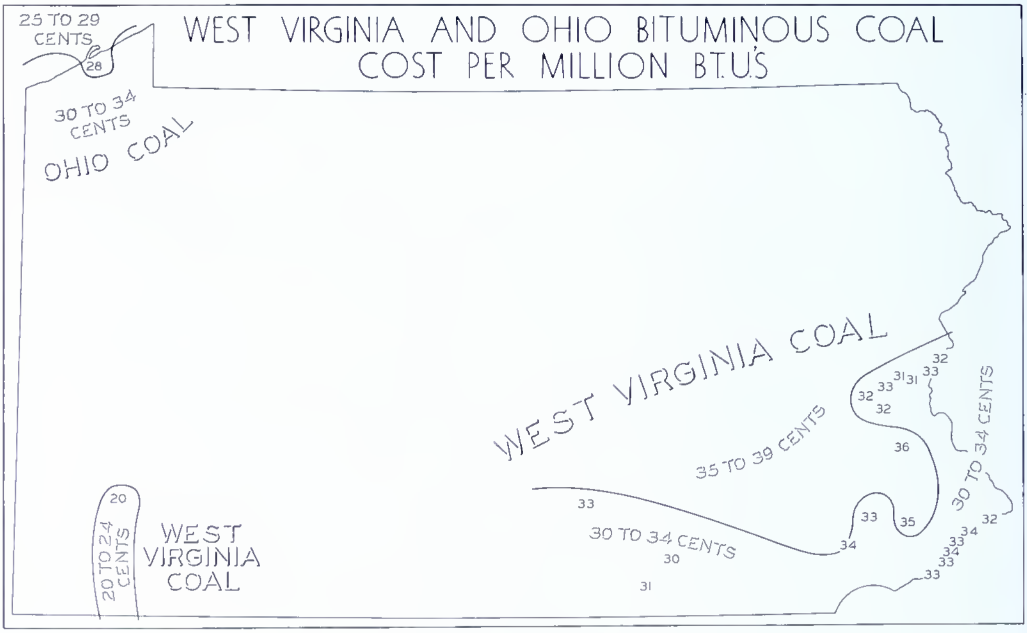

Fig. 13. Delivered Cost per Million B.T.U.'s of West Virginia and Ohio Bituminous Coal Consumed at Selected Electric Generating Plants in Pennsylvania, 1956. Figures are calculated to the nearest whole cent. Generalized probable cost isolines are also shown. Source: personal communications.

Such figures indicate that, on the whole, West Virginia coal is somewhat lower in cost than Pennsylvania bituminous coal sold in the same area, since cost figures for the latter fuel range from $9.03 to $10.02, with most plants paying between $9.00 and $9.50 (compare Figs. 8 and 12). The cost advantage of West Virginia coal is especially apparent in territory close to the southeastern and eastern Pennsylvania borders; the cost differential tends to disappear inward from these border areas.

The lone generating plant in southwestern Pennsylvania burning West Virginia coal and reporting cost figures has a per ton cost of $4.87, which is only slightly higher than the $4.72 cost for a similarly located plant employing Pennsylvania bituminous coal (compare Figs. 8 and 12). Cost data on West Virginia coal are not available for generating plants using such fuel and located in the northwestern and north-central parts of the Commonwealth (compare Figs. 4 and 12).

The delivered costs of West Virginia coal in southern Pennsylvania are represented on a B.T.U. basis in Figure 13. The cost pattern on this map is slightly at variance with that on the preceding one, but in essentials the two are similar and the relative competitive positions of West Virginia and Pennsylvania coal remain approximately the same as described above. The main value of the second map will become apparent later when the matter of competition between anthracite and bituminous coal is treated, since valid cost comparisons between these two fuels is possible only on a B.T.U. basis due to marked differences in heat value per ton.

Explanation of West Virginia Coal's Competitive Capabilities. An analysis of the above cost pattern, and of factors enabling West Virginia coal to enter southern Pennsylvania utility markets, resolves itself into a study of the same five components of delivered cost previously mentioned in the case of Pennsylvania bituminous coal, namely: (1) the B.T.U. content of the coal, (2) mining and processing expenses, (3) mining and processing profits, (4) delivery expenses, and (5) delivery profits. These factors, and/or their products, are shown in composite form on the map in Figure 14, and continual reference to this map is made in the materials immediately following.

As stated earlier, a synthesis of the first three factors may be expressed in terms of F.O.B. mine values of coal. Such mine values, on a county basis and stated in dollars and cents, are given in Figure 14 for bituminous coal producing counties of Pennsylvania and West Virginia (U. S. Bureau of Mines, 1953, p. 122, 123, 125). The same map shows, by means of a heavy labelled line, the boundaries of significant coal production; and by means of diagonal ruling, the major coal producing

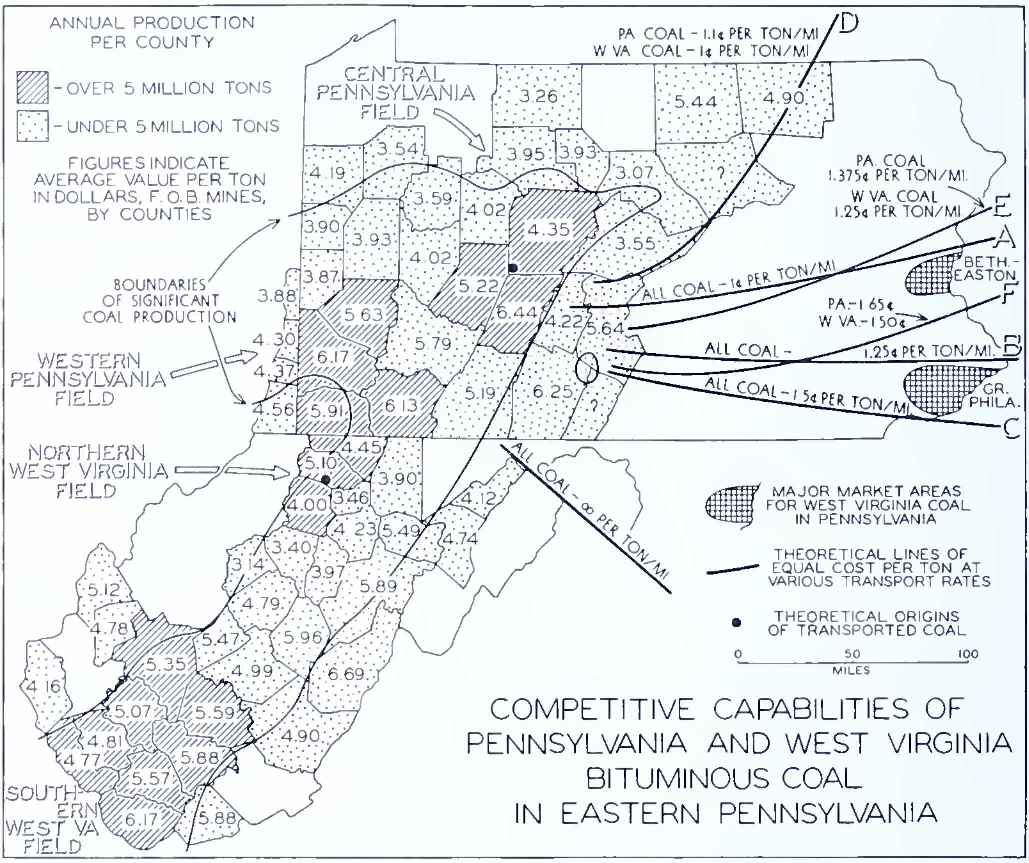
ANNUAL PRODUCTION PER COUNTY
▨ - OVER 5 MILLION TONS
▒ - UNDER 5 MILLION TONS
FIGURES INDICATE AVERAGE VALUE PER TON IN DOLLARS, F.O.B. MINES, BY COUNTIES
BOUNDARIES OF SIGNIFICANT COAL PRODUCTION
WESTERN PENNSYLVANIA FIELD
NORTHERN WEST VIRGINIA FIELD
SOUTHERN WEST VA FIELD
CENTRAL PENNSYLVANIA FIELD
PA COAL - 1.1¢ PER TON/MI
W VA COAL - 1¢ PER TON/MI
D
PA. COAL 1.375¢ PER TON/MI.
W VA. COAL 1.25¢ PER TON/MI
E
A
BETH.-EASTON
ALL COAL - 1¢ PER TON/MI
F
PA.-1.65¢
W VA.-1.50¢
ALL COAL - 1.25¢ PER TON/MI.
B
ALL COAL - 1.5¢ PER TON/MI
GR. PHILA.
C
ALL COAL - ∞ PER TON/MI
3.26
5.44
4.90
3.54
3.95
3.93
3.07
?
4.19
3.59
4.02
4.35
3.90
3.93
3.55
4.02
3.87
5.22
3.88
5.63
6.44
4.22
5.64
4.30
6.17
5.79
4.37
5.19
6.25
4.56
5.91
6.13
?
4.45
5.10
3.90
4.00
3.46
4.12
4.23
5.49
4.74
3.40
3.14
3.97
5.89
5.12
4.79
4.78
5.47
5.96
5.35
4.99
6.69
4.16
5.07
5.59
4.81
4.90
4.77
5.88
5.57
6.17
5.88
MAJOR MARKET AREAS FOR WEST VIRGINIA COAL IN PENNSYLVANIA
THEORETICAL LINES OF EQUAL COST PER TON AT VARIOUS TRANSPORT RATES
THEORETICAL ORIGINS OF TRANSPORTED COAL
0
50
100
MILES
COMPETITIVE CAPABILITIES OF PENNSYLVANIA AND WEST VIRGINIA BITUMINOUS COAL IN EASTERN PENNSYLVANIA

Fig. 14. Competitive Capabilities of Pennsylvania and West Virginia Bituminous Coal in the Electric Generating Markets of Eastern Pennsylvania, 1953. Refer to text for an analysis of the map. Sources: U. S. Bureau of Mines, 1953, p. 122, 123, 125, personal communications, and authors' calculations.

counties of both states, i.e., those yielding over five million tons annually (U. S. Bureau of Mines, 1953, p. 122, 123, 125) and which therefore can supply large quantities of coal for shipment to electric generating plants and other industrial establishments in southeastern and south-central Pennsylvania. It is evident from such data that there are four groups of major bituminous coal producing counties in the two states, namely the three counties forming the core of the Central Pennsylvania Field, the four counties constituting the core of the Western Pennsylvania Field, the three core counties of the Northern West Virginia Field, and the eight core counties of the Southern West Virginia Field (Fig. 14). Inspection of the coal value figures and locations of the four groups of counties reveals that only two of the four groups meet the necessary requirements of both (1) relatively low F.O.B. mine values of coal, and (2) relatively close proximity to southeastern and south-central Pennsylvania coal markets—namely, the core counties of the Central Pennsylvania Field and those of the Northern West Virginia Field (Fig. 14). Hence, it is not unexpected to find that correspondence received by the authors indicates that these two groups of counties constitute the major sources of supply for bituminous coal consumed in the electric generating plants of southeastern and south-central Pennsylvania.

However, it should be noted that there are marked differences in coal values, and distances from markets, between the core counties of the Central Pennsylvania Field and those of the Northern West Virginia Field. The average weighted value of all coal produced in the Central Pennsylvania group of counties is $5.60 per ton F.O.B. mine, whereas the figure for the Northern West Virginia group of counties is only $4.56 (U. S. Bureau of Mines, 1953, p. 122, 123, 125). In contrast, distances from the Central Pennsylvania group of counties to markets in southeastern and south-central Pennsylvania average 50 to 100 miles less than distances from the Northern West Virginia group of counties to the same markets (Fig. 14). In other words, the Pennsylvania group has a competitive advantage in terms of delivery expenses, whereas the West Virginia group has a competitive advantage in terms of production expenses. The problem posed, therefore, is one of determining the mechanics underlying the present state of balance, whereby production expense advantages of the West Virginia coal producing counties counterbalance delivery expense advantages of the Pennsylvania bituminous coal producing counties, and result in a zone of active market competition in southeastern and south-central Pennsylvania.

It should be pointed out in connection with this problem that two components enter into over-all delivery expenses, namely fixed charges (such as loading and unloading expenses, insurance, transportation taxes, and handling charges of coal merchants) that are wholly or largely independent of the mileage involved, and variable charges that are dependent upon the mileage between mine and generating plant. The former charges for purposes of this study are assumed to be the same per ton of coal moved, regardless of whether it originates in the Northern West Virginia Field or the Central Pennsylvania Field and regardless of whether the coal moves as little as 50 miles or as much as 300 miles. Such charges, in effect, are merely a uniform addition to the F.O.B. mine value of coal no matter where it is mined or how far it is moved, and can be ignored in an analysis of differences in delivery expenses between the two coal mining areas and the market area. The latter, or variable, charges are those that are dealt with here and that are mapped on Figure 14.

A number of hypothetical cases for such variable charges are here-with set up, and the results of each of these cases are shown on Figure 14. If variable transportation charges average 1 cent per ton/mile[7] for both Pennsylvania and West Virginia bituminous coal, and if to these variable charges are added fixed transportation charges of unspecified but uniform amount per ton, together with previously specified average F.O.B. mine values per ton for each of the two coal mining areas under consideration ($5.60 and $4.56 per ton), then the line of theoretically equal delivered costs for both Central Pennsylvania and Northern West Virginia bituminous coal originating at theoretical centers of origin within those areas (large black dots on Fig. 14) is represented by line "A" on Figure 14. To the north of this line, bituminous coal from Central Pennsylvania has the lower average delivered cost, and hence a competitive market advantage; to the south of this line, bituminous coal from Northern West Virginia has the lower average delivered cost and hence a competitive market advantage. If, instead, all of the above conditions remain the same excepting that variable transportation charges are increased to an average of 1.25 cents per ton/mile for both Pennsylvania and West Virginia bituminous coal, then line "B" on Figure 14 represents the line of theoretically equal delivered costs for both Central Pennsylvania and Northern West Virginia bituminous coal. Similarly, line "C" represents the line of equal delivered costs if variable transportation charges on coal from both sources average 1.5 cents per ton/mile. It is evident from the positions of the above lines on Figure 14 that any increase in variable transportation charges reduces the area of competitive advantage for Northern West Virginia coal and correspondingly increases the area of competitive advantage for Central Pennsylvania coal. An increase in variable transportation charges to infinity produces a line of equal delivered costs whose every point is equidistant from the theoretical centers of origin in both the Central Pennsylvania and the Northern West Virginia fields, since under such hypothetical circumstances the production cost advantage of Northern West Virginia coal is of zero importance (see infinity line on Fig. 14).

The matter of competition between Central Pennsylvania and Northern West Virginia coal in electric generating markets of southeastern and south-central Pennsylvania is complicated, moreover, by still another factor. Some authorities claim, although it is difficult to prove because of the complexities of the transportation systems connecting mines and generating plants, that West Virginia coal enjoys a more favorable freight rate structure than Pennsylvania coal. If such an advantage for West Virginia coal exists, and if it is in the order of magnitude of 10 per cent of the variable transportation charges, then rates of 1.1 cents per ton/mile on bituminous coal from Central Pennsylvania and of 1 cent per ton/mile on Northern West Virginia coal result in a line of theoretically equal delivered costs (line "D" on Fig. 14) that diverts the electric generating market of almost the entire eastern part of Pennsylvania to Northern West Virginia coal. If, instead, variable transportation charges for Central Pennsylvania coal are 1.375 cents per ton/mile, and for Northern West Virginia coal 1.25 cents per ton/mile, then line "E" on Figure 14 represents the line of theoretically equal delivered costs. Similarly, variable transportation charges per ton/mile of 1.65 cents for Central Pennsylvania coal and 1.50 cents for Northern West Virginia coal produce line "F" on Figure 14. Just which line of theoretically equal delivered cost, "A" through "F" or some other line, represents the present average competitive boundary between Central Pennsylvania and Northern West Virginia coal in the southeastern and south-central Pennsylvania electric generating market cannot be stated with assurance. Some variant of line "E" or "F," with abnormalities introduced by the freight rate structure, apparently most nearly matches the delivered cost per ton figures for Pennsylvania and West Virginia bituminous coal given on Figures 8 and 12. Such a line delimits the territories most effectively served by Pennsylvania and by West Virginia bituminous coal producers under existing circumstances, and explains the considerable share of the southeastern and south-central Pennsylvania electric generating market that has been captured by West Virginia coal.

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[7] The average revenue per ton/mile for bituminous coal originated by Class I railroads in the United States during 1955 was 1.11 cents, and the average length of haul was 291 miles, according to data supplied by the Interstate Commerce Commission and quoted in *Bituminous Coal Trends,* National Coal Association, Washington, D.C., 1956, p. 33. In many cases, actual per ton/mile figures are modified by the fact that coal moves by a combination of rail and truck routes, and is handled partly by common carrier and partly by private or contract carrier.

Still to be determined, in this section of the study, are the factors that result in lower coal values F.O.B. mine in core counties of the Northern West Virginia Field as compared with higher coal values F.O.B. mine in core counties of the Central Pennsylvania Field. The proximate factor is the higher tonnage mined per man/day in the former area (from 9 to 14 tons[8] on a county average basis) as compared with the lower tonnage mined in the latter area (from 5 to 8 tons; see Fig. 15A; U. S. Bureau of Mines, 1953, p. 122-125). Behind this evident cause, however, are a group of basic factors which together account at least in part for the higher labor productivity in the Northern West Virginia Field. Coal seams being mined in this area are almost twice as thick on the average (6.4 feet) as those being used in the Central Pennsylvania Field (3.6

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[8] Fractions of a ton are omitted in the text and on the map.

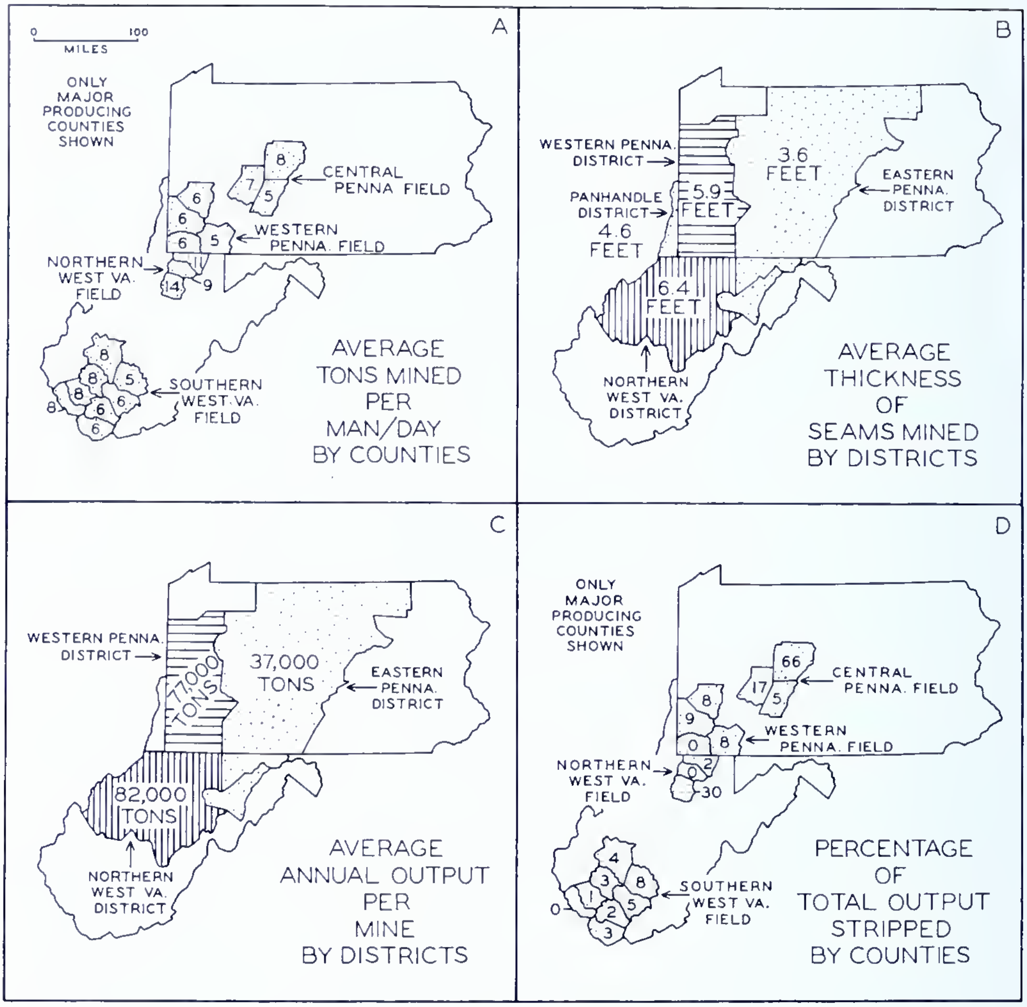

Fig. 15. Selected Factors Influencing the Competitive Capabilities of Pennsylvania and West Virginia Bituminous Coal, 1953. The "districts" indicated refer to the standard bituminous coal production districts, first defined in the Bituminous Coal Act of 1937. Sources: U. S. Bureau of Mines, 1953, p. 79-81, 122-125 and Young and Anderson, 1952, p. 5.

feet; see Fig. 15B; Young and Anderson, 1952, p. 5), with consequent lower production costs and greater output per miner. Moreover, mines in the Northern West Virginia Field yield on the average more than twice the annual output (82,000 tons) of those in the Central Pennsylvania Field (37,000 tons; see Fig. 15C; Young and Anderson, 1952, p. 5), and tend to be somewhat more mechanized and efficient (U. S. Bureau of Mines, 1953, Tables, p. 55, 56, 59, 61, 62, 87, 91). Indeed, the only factor that enables Central Pennsylvania core counties to attain present per man/day tonnage figures, despite the handicaps to coal mining in the area, is the high degree to which stripping has been developed as compared with Northern West Virginia core counties (Fig. 15D).

With regard to competition of West Virginia with Pennsylvania bituminous coal in southwestern Pennsylvania, along the navigable lower Monongahela River and connecting navigable waters of the lower Allegheny and upper Ohio rivers, reference should again be made to basic maps in Figures 4 and 7. Note that three generating plants (#2, #26, #54), located like many others in the same general vicinity along the above three rivers, receive all or part of their fuel from mines located along the Monongahela River in the Northern West Virginia Field. Data on delivered costs per ton and per million B.T.U.'s are available, however, only for one of the generating plants (#2), the figures being $4.87 and 20 cents respectively (Figs. 12 and 13). Such costs are competitive with those of another plant (#3) located nearby, which utilizes only Pennsylvania bituminous coal from mines along the Monongahela ($4.72 and 20 cents; see Figs. 8 and 9).

The ability of Northern West Virginia coal to enter the coal producing territory of southwestern Pennsylvania is attributable in large measure to the low rate per ton/mile for river transportation,[9] and to the low value per ton F.O.B. mine of Northern West Virginia coal (Fig. 14). The inability of Northern West Virginia coal to take over an even larger segment of the southwestern Pennsylvania electric generating market than at present probably is due chiefly to the concentration of that market in the Greater Pittsburgh area which is located some 30 to 70 miles north of the West Virginia border, rather than in the extreme southwestern part of Pennsylvania (Figs. 1 and 2). Thus, transport expenses for West Virginia coal are increased; and at the same time the Greater Pittsburgh market, outside of the congested area of the city itself, has easy access to relatively low cost stripped coal mined locally or mined immediately to the north (Fig. 10). Moreover, some of the Greater Pittsburgh generating plants (for example, #7 and #8) are not located on a navigable river, and hence cannot profit to the maximum extent from low river transport rates for West Virginia coal; and other generating plants (for example, such municipal and industrial plants as #13, #18, #19, #20, and #57) have such limited coal needs that they cannot handle, store, and utilize barge load quantities of at least 750 tons, whereas they can take carload lots of 50 tons (Seawall, 1957, p. 215-216). Undoubtedly, the relative significance of barged West Virginia coal in southwestern Pennsylvania's electric generating market is somewhat greater than might be inferred from Figure 4, for no cost figures or information on origin of coal were made available to the authors by companies operating a number of medium capacity electric generating plants in the Greater Pittsburgh area, coal for which is believed to come at least in part from the Northern West Virginia Field.

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[9] Approximately 0.5 cents per ton/mile on the average by contract or common carrier, and 0.3 to 0.4 cents per ton/mile by company owned barges (Seawall, 1957, p. 210-217).

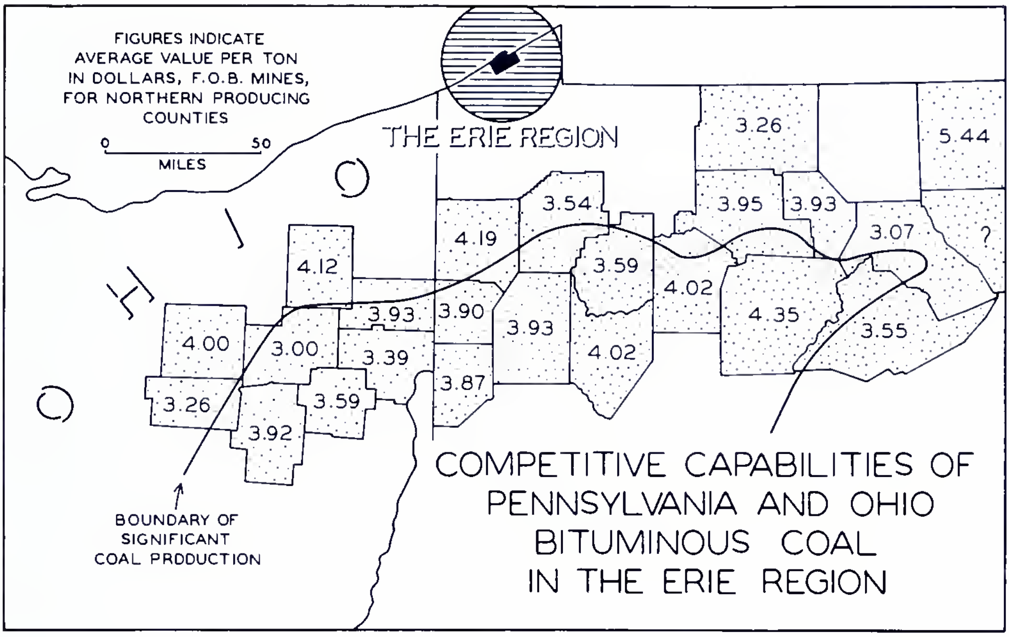
It can be stated, in summary, that the Northern West Virginia coal industry's ability to acquire a significant outlet for its product in the electric generating market of southern Pennsylvania is dependent primarily upon the availability of thick coal seams and upon a relatively high degree of mechanization. These advantages result in low coal values F.O.B. mine, which, combined with an advantageous freight rate structure toward the northeast and low-cost river transport facilities toward the north, enable West Virginia coal to overcome the handicap of distance and invade the utility market of much of southern Pennsylvania.

OHIO BITUMINOUS COAL

Unlike its West Virginia counterpart, Ohio bituminous coal plays only a minor role in the electric generating industry of Pennsylvania, despite the presence of Ohio coal along or in the vicinity of much of the western Pennsylvania border. Only four generating plants (#21, #42, #43, #76) are known to employ the Ohio fuel, two in the Erie area and one each in Pittsburgh and Altoona (Fig. 4). The latter two plants represent a special case, as has previously been pointed out, since they are operated by the Pennsylvania Railroad and thus obtain special transportational advantages. The lone region, therefore, in which Ohio coal apparently competes on equal terms with Pennsylvania bituminous coal in the Commonwealth is the Erie area.

Delivered cost data on Ohio coal for the two Erie generating plants indicate that, on a per ton basis, one plant pays $7.62 and the other $8.44 (Fig. 12); and on a heat value basis the one plant for which data are available pays 28 cents per million B.T.U.'s (Fig. 13). Such costs are somewhat higher on a per ton basis than those for Pennsylvania bituminous coal delivered to five reporting plants in the Erie area, namely from $6.57 to $7.39 (Fig. 8). On a per million B.T.U.'s basis, however, the costs of Pennsylvania bituminous coal at the five plants are approximately the same (25 to 29 cents) as that of Ohio coal (Figs. 9 and 13).

Factors underlying the competitive capabilities of Ohio and Pennsylvania bituminous coal are represented on the map in Figure 16, which indicates average values per ton of coal F.O.B. mine for all producing counties of both states in the vicinity of the Erie area, together with the northern boundary of significant coal production in the two states. Note that, in terms of mine value of coal, the Ohio mining counties with significant production have a slight (approximately 10 to 50 cents) cost


FIGURES INDICATE AVERAGE VALUE PER TON IN DOLLARS, F.O.B. MINES, FOR NORTHERN PRODUCING COUNTIES
0
50
MILES
THE ERIE REGION
O
H
I
O
3.26
5.44
3.54
3.95
3.93
4.19
3.07
?
4.12
3.59
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4.00
3.00
3.39
4.02
3.87
3.26
3.59
3.92
BOUNDARY OF SIGNIFICANT COAL PRODUCTION
COMPETITIVE CAPABILITIES OF PENNSYLVANIA AND OHIO BITUMINOUS COAL IN THE ERIE REGION

Fig. 16. Competitive Capabilities of Pennsylvania and Ohio Bituminous Coal in the Electric Generating Market of the Erie Region, 1953. Refer to text for an analysis of the map. Source: U. S. Bureau of Mines, 1953, p. 121-123.

advantage over their Pennsylvania competitor counties, values ranging in the former area from $3.00 to $3.93 and in the latter area from $3.54 to $4.02. But, as a counterbalance, the boundary of significant coal production in the Pennsylvania counties is situated some 20 miles closer to Erie than the same boundary in the Ohio area, thus affording the Pennsylvania producer a variable transportation expense advantage of probably several tens of cents. Any attempt by Ohio producers to capture Pennsylvania electric energy markets east of Erie, of course, are prevented by prohibitive additions to variable transportation expenses. Likewise, capture of Pennsylvania electric energy markets within the western part of the Pennsylvania bituminous coal fields themselves is difficult because of the presence of competitively priced local coal (Fig. 16).

The primary reason why the Ohio bituminous coal industry is unable to overcome the handicap of distance and seriously encroach upon the Erie electric energy market is that tonnages mined per man/day in Ohio producing counties average no higher (from 8 to 15 tons, on a county average basis, for the counties within the boundary of significant coal production shown in Fig. 16) than tonnages obtained from competing counties immediately to the east in Pennsylvania—from 7 to 16 tons

(Bureau of Mines, 1953, p, 121-123).[10] The comparability of these tonnage figures results from the fact that neither group of counties has appreciable natural or engineering advantages in coal mining. Average seam thicknesses are approximately the same in both groups—5.9 feet in the Western Pennsylvania District, Fig. 15B; 4.2 feet in all coal mining counties of the Eastern Ohio District (Young and Anderson, 1952, p. 5); average annual output per mine in the two Districts is not greatly different—77,000 tons in the Western Pennsylvania District, Fig. 15C; 55,000 tons in the Eastern Ohio District (Young and Anderson, 1952, p. 11); and percentage of strip mining (U. S. Bureau of Mines, 1953, p. 78, 121) and degree of mechanization of underground mining (U. S. Bureau of Mines, 1953, p. 55, 56, 59, 61, 62, 87, 91) are comparable, although Ohio leads in both instances. Hence, the Ohio bituminous coal industry lacks the competitive advantages that enable the West Virginia industry to assume a significant role in the Pennsylvania electric generating industry.

ANTHRACITE

The dominance of anthracite in the electric generating market of east-central Pennsylvania is virtually complete. All except one of the 20 generating plants in the Anthracite Coal Zone in Figure 3 burn such fuel exclusively, and the exception (#120) depends upon anthracite for more than three-fourths of its energy requirements (fuel oil supplies the remainder). Moreover, anthracite meets various percentages of the fuel needs of seven additional generating plants in the Anthracite-Bituminous Coal Transition Zone (Fig. 3).

On the other hand, a noteworthy aspect of the fuel situation in Pennsylvania is the inability of the anthracite industry to capture markets located more than a short distance from the coal fields (compare Figs. 3 and 7). The isolated anthracite burning plant in the southeastern part of Pennsylvania (#109) is an exception, but it uses fines dredged locally from the lower Susquehanna River. Pennsylvania and West Virginia bituminous coal operators find outlets in many Commonwealth generating plants located 100 to 300 miles from the coal fields, and fuel oil and gas producers market their products at various sites scattered throughout the State, but anthracite producers apparently are unable to supply the fuel needs of electric generating plants situated more than approximately 30 miles from the margins of the mining areas.

An understanding of these and other spatial aspects of the electrical market for anthracite in Pennsylvania requires analysis of the delivered cost pattern for the fuel, and a study of the factors that have produced such a cost pattern. The two basic questions involved are: (1) why does the anthracite industry so completely dominate the local and nearby generating market, and (2) why does the industry fail to extend its present market area to southern and eastern Pennsylvania regions that are lacking in fuel supplies of their own? Additional, secondary, questions relating to internal differences in delivered costs are also posed and answered in the section that follows.

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[10] Fractions of a ton are omitted.

Cost Data and the Cost Pattern. Delivered cost figures for anthracite in the main area of utilization show average costs ranging from $3.23 to $8.03 per ton on a plant by plant basis (Fig. 17). Three plants report fuel costs of below $3.99 per ton, 4 plants from $4.00 to $4.99, 4 plants from $5.00 to $5.99, 3 plants from $6.00 to $6.99, 2 plants from $7.00 to $7.99, and one plant over $8.00. Costs tend to be lowest over a relatively large zone on, or in the immediate vicinity of, the southern and middle anthracite fields; and in a limited zone associated with the northern anthracite field (Fig. 19A). Costs increase rapidly near the periphery of the anthracite-using territory, and generalized probable cost isolines there become exceptionally closely spaced. It is realized that the 17 stations upon which such isolines are based are too few in number to permit construction of equal cost lines with any degree of assurance, and that undoubtedly the pattern shown is crude and inaccurate in detail. Nevertheless, the main features of the areal cost structure are believed to be correct.

Such a pattern of isolines is in marked contrast to that found on the equivalent cost map for Pennsylvania bituminous coal, where isolines with few exceptions are considerably more widely spaced (compare Figs. 8 and 17). Presumably, therefore, in the case of anthracite, some factor (s) causes a very rapid increase in delivered costs at a distance of a few tens of miles from the mining areas.

Also to be pointed out on the anthracite cost map is the pronounced eastward extension of the lower value isolines in the form of a long finger pointing toward Easton and the New Jersey border (Fig. 17). Here, again, some factor (s) operates to enable anthracite to sell at a relatively low delivered cost beyond the otherwise prevalent distance from the coal fields.

A second anthracite cost map, Figure 18, represents delivered costs at 16 generating plants in the main area of utilization on a per million B.T.U.'s basis. Such a map permits more accurate cost comparisons than the previous map between anthracite and both Pennsylvania and West Virginia bituminous coal, for the average heat value of a ton of anthracite

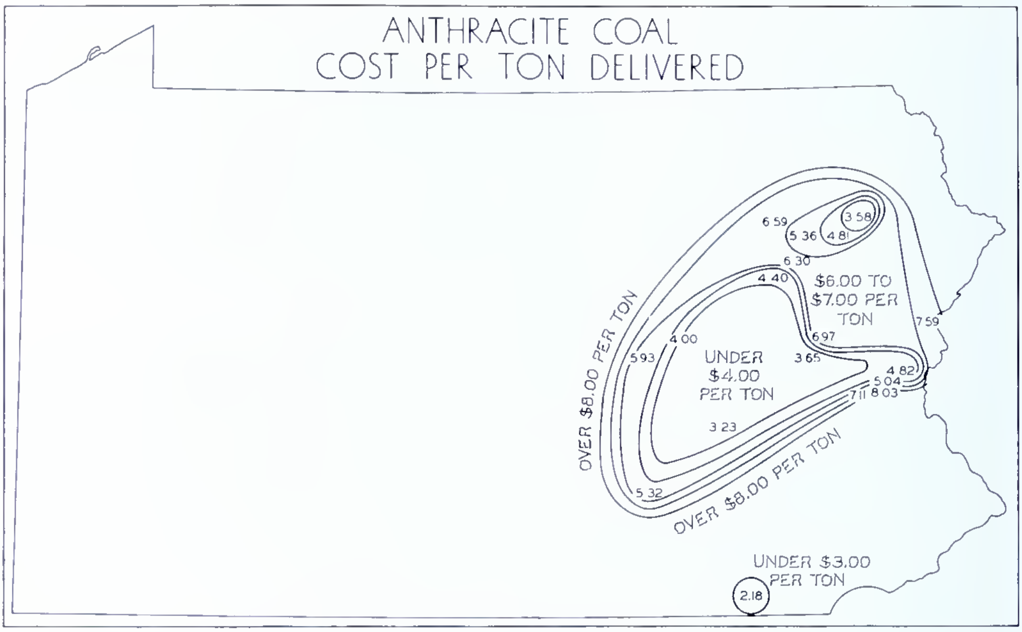

Fig. 17. Delivered Cost Per Ton of Pennsylvania Anthracite Coal Consumed at Selected Electric Generating Plants in Pennsylvania, 1956. Generalized probable cost isolines are also shown. Source: personal communications.

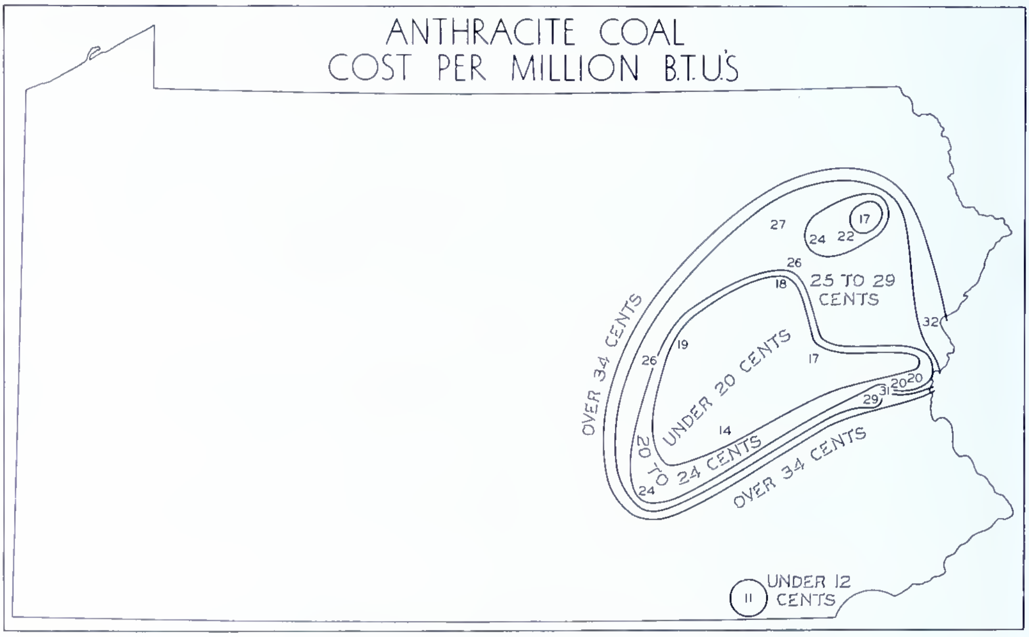

Fig. 18. Delivered Cost Per Million B.T.U's of Pennsylvania Anthracite Coal Consumed at Selected Electric Generating Plants in Pennsylvania, 1956. Figures are calculated to the nearest whole cent. Generalized probable cost isolines are also shown. Source: personal communications.

is appreciably lower than the comparable figure for bituminous coal. For example, of the 90 generating stations employing bituminous coal for all or part of their energy requirements, and reporting to the authors on the average heat value of the coal they burn on an "as received" basis, 54 give B.T.U.s/lb. in the 13,000 to 13,999 range and 26 give B.T.U.'s/lb. in the 12,000 to 12,999 range. In contrast, of the 20 generating stations employing anthracite for all or part of their energy requirements, and reporting to the authors on the average heat value of the coal they burn on an "as received" basis, 11 give B.T.U.'s/lb. in the 11,000 to 11,999 range, 4 give B.T.U.'s/lb. in the 10,000 to 10,999 range, and 4 give B.T.U.'s/lb. in the 12,000 to 12,999 range.

The pattern of isolines on this map, Figure 18, is quite similar to that on the previous map. Two low cost, coal-field oriented core areas, with a finger extending from the large southern one eastward toward New Jersey, are surrounded by closely spaced isolines indicating a rapid rise in cost of the fuel at relatively short distances from the mining areas.

Comparison of this map with equivalent cost maps for Pennsylvania and West Virginia bituminous coal, all calculated on a per million B.T.U.'s basis (Figs. 9, 13, and 18), explains the inability of anthracite producers to expand their electric generating market. To the west, south, and east of the anthracite-using region, the cost of bituminous coal is as low as, or lower than, that of anthracite. Conversely, on the anthracite fields and in their near vicinity, neither Pennsylvania nor West Virginia coal can compete on a delivered cost basis with the local fuel, for transportation charges from distant bituminous fields raise delivered costs to perhaps between 50 and 100 per cent above those for anthracite (under 20 cents for anthracite, compared with an estimated 34 and 40 cents for Pennsylvania and West Virginia bituminous coal, respectively). Hence, within their own limited stronghold, the anthracite mining companies appear impregnable; but immediately beyond, they face the competition of lower cost bituminous coal.

Explanation of the Cost Pattern. A study of factors that produce the anthracite delivered cost pattern in Pennsylvania revolves around the same five components mentioned previously in connection with Pennsylvania and West Virginia bituminous coal: (1) the B.T.U. content of the coal, (2) mining and processing expenses, (3) mining and processing profits, (4) delivery expenses, and (5) delivery profits. The first three components may be jointly expressed in terms of F.O.B. breaker values (i.e., sales realizations) of anthracite. Such breaker values, however, differ widely even at a given preparation plant, for anthracite is marketed in a variety of sizes having considerable range in value. Table I, below, indicates average sales realization figures per net ton, and per million B.T.U.'s, on local sales for 10 sizes of anthracite within the mining area as a whole. Since, without exception, anthracite-burning electric generating plants reporting size of coal employed to the authors specified one or a combination of the three lowest priced sizes, only figures in Table I relative to these sizes are germane to this study. In other words, the anthracite employed in generating plants located on the coal fields ranges in average value F.O.B. breaker from $2.84 to $5.25 per ton, or from 11 cents to 21 cents per million B.T.U.'s. The latter pair of figures is competitive with those for Pennsylvania bituminous coal F.O.B. mine, which range from 11 cents to 23 cents per million B.T.U.'s on a county average basis (Fig. 10); and undoubtedly is approximately competitive with figures for West Virginia bituminous coal. Hence, on its home grounds so to speak, anthracite is in a position to virtually monopolize the electric generating market, since mining and processing expenses are equal to, and delivery expenses are much lower than, those for competing bituminous coal. In effect, the larger domestic and space heating sizes of anthracite bear the burden of carrying the inherently more expensive extraction and processing operations associated with anthracite mining, thus enabling the smaller sizes to compete with other fuels for the industrial market.

TABLE I.—AVERAGE SALES REALIZATION ON LOCAL SALES OF PENNSYLVANIA ANTHRACITE F.O.B. BREAKER, BY SIZE, 1955[1]

Size	*Dollars Per Net Ton*	*Cents Per Million B.T.U.'s*[2]
Broken and Lump	10.86	43
Egg	11.25	44
Stove	11.33	45
Chestnut	11.97	47
Pea	9.86	39
Buckwheat No. 1	7.89	31
Buckwheat No. 2	7.12	28
Buckwheat No. 3	5.25	21
Buckwheat No. 4	3.72	15
Buckwheat No. 5 and others (including silt)	2.84	11

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[1] Data from *Pennsylvania Anthracite in 1955*, U. S. Bureau of Mines, Mineral Market Report No. MMS 2592, Feb. 1957, p. 15. Figures indicate value at which coal left possession of producing company; margins of separately incorporated sales companies are excluded.

[2] Computed to the nearest whole cent on the basis of 12,700 B.T.U.'s per pound of clean, dry anthracite, the standard heat value figure employed by the U. S. Bureau of Mines (*Minerals Yearbook, Vol. II, Fuels,* 1953, p. 1).

An examination of regional differences in average anthracite values F.O.B. breaker, on local sales within the producing areas, affords explanation of the greater availability of low delivered cost anthracite (under

$4.00 per ton) in the southern part of the producing territory than in the north (Fig. 17). In the low-cost southern (Schuylkill) trade region (Fig. 19B) average local sales prices on No. 3, No. 4, and No. 5 buckwheat[11] are only $4.76, $3.60, and $2.49 respectively (see Table II). The high-cost northern (Wyoming) trade region, in contrast, charges average local prices of $5.50, $3.92, and $2.88 for the same sizes of coal. The central, Lehigh, trade region need not be considered here, since very little of its output of such coal sizes is sold locally (Table II). Basic cause for the price differential between north and south is the fact that the intensely folded and repeatedly outcropping anthracite seams of the south afford numerous opportunities for stripping, with resulting emphasis upon such high-yielding and low-cost operations (Fig. 19C). In the north, however, anthracite seams are mostly flat lying and they outcrop infrequently, thus necessitating mostly low-yielding and high-cost underground operations (Fig. 19C). In fact, the only reason that the Wyoming trade region can compete as effectively as it does in terms of sales price of its product is due to the fact that mechanization of underground mining is much more prevalent here than in the south (Fig. 19D).

TABLE II.—LOCAL SHIPMENTS, AND AVERAGE SALES REALIZATION ON LOCAL SALES F.O.B. BREAKER, OF PENNSYLVANIA ANTHRACITE, BY TRADE REGIONS AND SELECTED SIZES, 1955[1]

Trade Region	*Item*	*Buck. No. 3*	*Buck. No. 4*	*Buck. No. 5*
Schuylkill	Local Shipments (Tons)	170,097	77,158	13,184
	Sales Realization per Ton	$4.76	$3.60	$2.49
Lehigh	Local Shipments (Tons)	20,306	1,585	4
	Sales Realization per Ton	$6.78	$5.35	$4.25
Wyoming	Local Shipments (Tons)	211,577	29,091	120,568
	Sales Realization per Ton	$5.50	$3.92	$2.88

[1] Data from *Pennsylvania Anthracite in 1955*, U. S. Bureau of Mines, Mineral Market Report No. MMS 2592, Feb. 1957, p. 9.

Investigation of the cause for the long finger-like eastward extension of isolines toward Easton and the New Jersey border on the anthracite delivered cost maps (Figs. 17 and 18) brings to light a peculiarity in the pricing system for the fuel. As Table III indicates, the anthracite industry sells its products on the basis of two distinct F.O.B. breaker pricing scales, one designed for the local market and the other applying to shipments outside the producing region. There is no fixed relationship between these two scales; the ratio between local and outside prices varies from one period of time to another, from one size of coal to another, from one

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[11] Here, and in the following discussion, whenever No. 5 buckwheat is mentioned it is assumed to include silt.

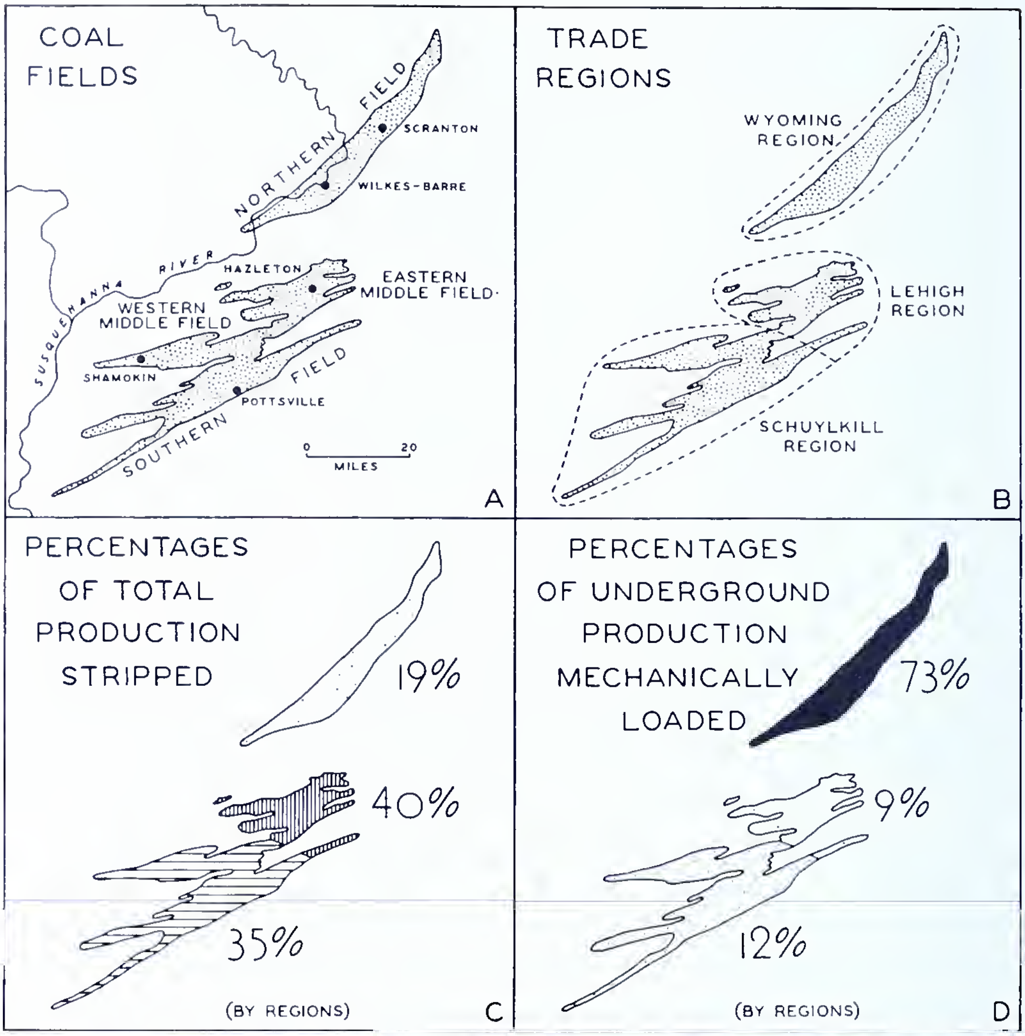

Fig. 19. Selected Aspects of the Anthracite Coal Mining Area of Pennsylvania. The anthracite deposits consist of four fields (Map A), but trade usage recognizes three regions (Map B). Data for maps C and D are for 1955. Source: U. S. Bureau of Mines, 1957, p. 8.

producing region to another, and indeed from one breaker to another. However, in recent years at least, the following set of conditions has prevailed. Producers in the Schuylkill trade region almost invariably charge higher average F.O.B. breaker prices for outside shipments of Nos. 3, 4, and 5 buckwheat than for local shipments, and the differential is appreciable (from 19 to 68 cents per ton in Table III). Producers in the Wyoming trade region fluctuate in their pricing policies, sometimes charging higher average F.O.B. breaker prices for outside shipments of various sizes and sometimes charging lower average prices, and in general the differential is small (from 4 to 21 cents per ton in Table III).

In contrast, producers in the Lehigh trade region almost invariably charge lower average F.O.B. breaker prices for outside shipments than for local shipments, and the differential is quite large (from $1.01 to $1.49 per ton in Table III). In effect, the Lehigh region therefore is primarily an "exporter" of coal, selling little locally and instead aiming its sights at, and providing preferential rates for, potential users of anthracite in the considerable market of the Bethlehem-Easton area (Fig. 2), where as a result it can meet on competitive terms the bituminous coal coming from Central Pennsylvania and Northern West Virginia fields (Fig. 3). Apparently, therefore, the eastward extension of the isolines toward Easton on the anthracite delivered cost maps is a price-induced extension of the "normal" area of coal-field oriented cheap anthracite.

TABLE III.—AVERAGE SALES REALIZATION ON LOCAL AND OUTSIDE SALES OF PENNSYLVANIA ANTHRACITE F.O.B. BREAKER, BY TRADE REGIONS AND SELECTED SIZES, 1955[1]

Size	*Schuylkill Region*		*Lehigh Region*		*Wyoming Region*	
	Local Sales	Shipped Outside Region	Local Sales	Shipped Outside Region	Local Sales	Shipped Outside Region
Buck. No. 3	$4.76	*$5.11*	*$6.78*	$5.29	*$5.50*	$5.46
Buck. No. 4	3.60	*3.79*	*5.35*	3.94	*3.92*	3.88
Buck. No. 5	2.49	*3.17*	*4.25*	3.24	2.88	*3.09*

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[1] Data from *Pennsylvania Anthracite in 1955,* U. S. Bureau of Mines, Mineral Market Report No. MMS 2592, Feb. 1957, p. 15. In all cases, the higher of the two figures for local versus outside prices is italicized.

Thus far in this section, attention has been directed to those factors that enable anthracite to dominate, or participate in, its local and nearby electrical energy markets; and to other, secondary, factors that produce internal variations in the delivered cost pattern of anthracite within such markets. There remains for treatment an analysis of the factor or factors that explain the close spacing of delivered cost isolines on the outer margin of the anthracite-using territory (Figs. 17 and 18), and the consequent inability of that fuel to compete effectively at even modest distances from its source with Pennsylvania and West Virginia bituminous coal.

A number of basic facts relevant to this situation are presented in Table IV. Inspection of the table indicates a striking difference in the mode of transportation employed for shipping anthracite to destinations within Pennsylvania as compared to destinations in other states. More than two-thirds of the fuel sold in Pennsylvania moves by truck, whereas trucking represents only minor percentages for other major markets. Moreover, the same table shows that over two-thirds of all anthracite trucked in Pennsylvania is destined for markets in the mining region itself; and most of the remaining one-third of the trucked coal (especially the relatively low value fine sizes) undoubtedly is marketed within a road distance of several tens of miles from the mining region. For destinations beyond such distances, whether within or outside the Commonwealth, shipments chiefly are made by rail.

Inspection of maps showing the location of Pennsylvania's anthracite-fueled electric generating plants (Fig. 3), and the location of the State's anthracite fields (Fig. 7), reveals that such plants are almost invariably located within an area lying less than approximately 30 miles distance from the margins of the coal fields. Hence, it is probable that anthracite is only competitive as a source of electrical energy when it can be transported to its destination via truck. Rail shipping charges on anthracite are so high (75 per cent higher than the rate for shipping bituminous coal, based on a one per cent sample of all audited carload waybills conducted by the Interstate Commerce Commission; Pa. Dept. of Commerce, 1952, p. 28) that, if such a mode of transportation is required for delivery, the fuel is non-competitive in cost with other alternative types and sources of energy for electric generation. Thus is explained the close spacing of delivered cost isolines on the outer margin of the anthracite-using area in Figures 17 and 18. Within this area, trucking is economically feasible, and except near the margins of the area delivered costs are relatively low. But beyond, where rail shipment generally is employed, delivered costs rise abruptly and the isolines are bunched together.

TABLE IV.—RAIL AND TRUCK SHIPMENTS OF PENNSYLVANIA ANTHRACITE, BY DESTINATIONS, 1955[1]

Destination	*By Truck* (Net Tons)	*By Rail* (Net Tons)
Pennsylvania		
Within Mining Region	4,270,472	0
Outside Mining Region	1,966,548	2,849,526
New York	947,785	5,411,825
New Jersey	752,161	4,381,062
New England	0	1,771,427
Maryland	70,065	257,795
Delaware	18,211	138,733
Others (including exports)	25,056	3,546,902

In summary, it is evident that the anthracite industry's ability to dominate the local and nearby electric generating market is dependent upon the preferential pricing treatment it accords the smaller sized industrial grades of its product, together with the availability of low cost truck transport for nearby delivery. Inability to compete in more distant electric generating markets is due in large measure to the high rail freight charges applied to its product, rather than to disproportionately high F.O.B. breaker costs. Within the anthracite market area, variations in cost of the fuel at electric generating plants are dependent upon regional differences in configuration of coal seams, and hence in mining processes and resultant production expenses; upon trucking distance between breaker and generating plant; and upon regional contrasts in local versus outside sales pricing policies.

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[1] Data from *Pennsylvania Anthracite in 1955,* U. S. Bureau of Mines, Mineral Market Report No. MMS 2592, Feb. 1957, p. 13. Figures do not include dredge coal, which accounts for about one per cent of total production.

FUEL OIL AND GAS

Fuel oil and gas are of relatively minor significance in the electric generating industry of Pennsylvania, for most plants using such energy types are of small capacity or obtain the bulk of their energy requirements from other types of fuel. Nevertheless, the sizable number of plants employing oil and gas, and their widespread distribution, warrant their investigation.

Figure 20 gives delivered costs per million B.T.U.'s at 18 plants using fuel oil and/or gas as a source of all or part of their energy requirements. Costs range from 29 to 87 cents. Extremely irregular and non-progressive

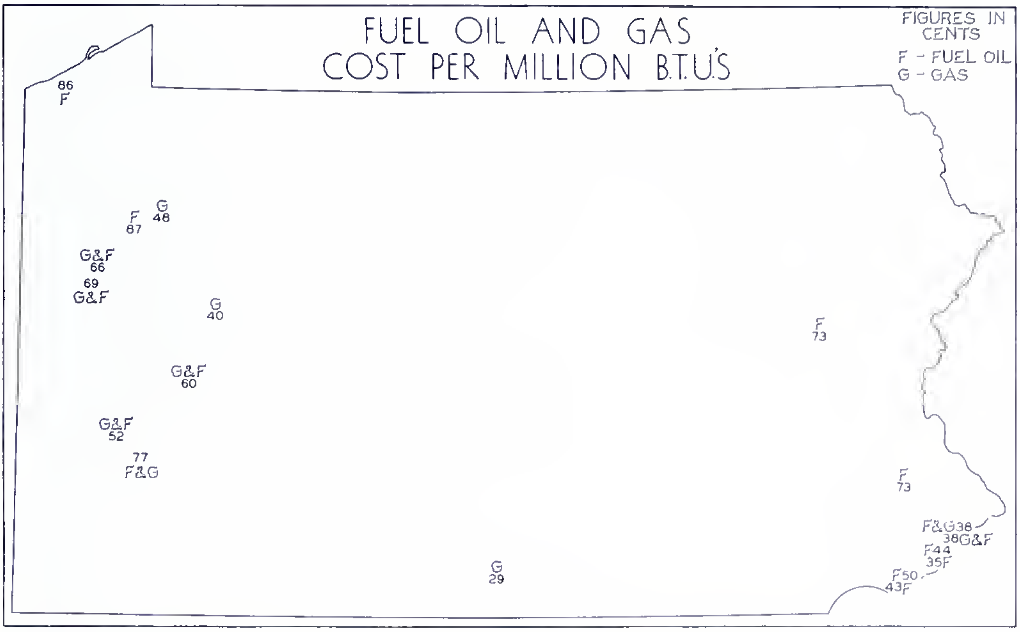

Fig. 20. Delivered Cost Per Million B.T.U.'s of Fuel Oil and/or Gas Consumed at Selected Electric Generating Plants in Pennsylvania, 1956. Figures are calculated to the nearest whole cent. Source: personal communications.

areal changes in cost figures make it impossible to construct probable cost isolines as is done on equivalent maps of anthracite and various bituminous coals. It is evident from the data given that neither gas nor oil, nor a combination of the two, is competitive with coal on a cost basis anywhere in the State except in the Greater Philadelphia area, where barge or tanker delivery of low cost, out-of-state crude petroleum and fuel oil is possible, and along main transcontinental pipe lines in energy deficient south-central and southeastern Pennsylvania (compare Fig. 20 with Figs. 9, 13, and 18). In these areas delivered costs, in cents per million B.T.U.'s, range from the high 20's to the low 40's. Elsewhere in the State such fuel costs typically range in cents from the 60's to the 80's, due to additional transportation charges on imported oil and gas, or to high production expenses in the State's own oil and gas fields. Obviously, some factor (s) other than initial cost of energy must be instrumental in dictating the choice of such fuels in preference to lower cost coal in many sections of the Commonwealth.

Communications from some users of fuel oil and gas indicate that cleanliness, convenience, dependability of supply, and ease of storage and handling as compared with coal are cogent factors. It should be noted that many such plants are owned and operated by, and are located within the boundaries of, small municipalities where the incentive toward cleanliness would be great, and where necessary finances for conversion to coal would be difficult to raise. In fact, 10 of the 16 municipally owned and operated generating plants in Pennsylvania for which data are available (#9, #17, #34, #41, #58, #62, #84, #106, #120, #141) burn oil and/or gas for all or part of their energy requirements.

Moreover, data relative to date of plant construction for generating plants located in Pennsylvania's oil and gas fields would appear to indicate that inertia inherent in historical use of local gas and/or oil plays a role in their continued employment, for most of these plants were constructed at a time when the State's production of such fuels was greater than today. Data on all but one of the fuel oil and/or gas using generating plants in the Natural Gas and Fuel Oil Zone of Figure 3 indicate that 9 of 12 were built before 1936 and 6 of 12 before 1925, one being constructed in 1902.

One might well raise the question as to why owners of many generating plants other than present users do not employ oil and/or gas. Certainly, there is no lack of suitable transport facilities for such fuels, since virtually the whole of Pennsylvania has a close network of gas, crude oil, and oil products pipe lines and roads. Apparently non-users (mainly private utilities and industrial concerns) are unwilling, or find it competitively impossible, to pay the price for such high cost energy no matter how desirable may be its non-monetary advantages. The trend, instead, is for private utility and industrial owners of generating plants outside the Greater Philadelphia area to close down those using gas and/or oil, or to convert them to coal. For example, a letter dated December 15, 1958 from the comptroller of the Pennsylvania Electric Company with reference to their gas-burning generating plant at Oil City (#37) states: "During 1958 (through November) generation at the Oil City Station was less than enough to provide for station service and no generation is scheduled for the station in 1959, 1960 or 1961 .. . . unless the station is required to operate to cover some emergency." As long as coal energy remains lower in cost than petroleum or gas energy, therefore, the likelihood of any major displacement of the former in the electric generating markets of Pennsylvania appears remote.

Hydro Power

The remaining significant source of energy for the electric generating industry of Pennsylvania is hydro power. As has previously been indicated, there are 10 hydroelectric plants in the State known to the authors, all localized within the three hydro zones and one hydro node shown on Figure 3.

Comparison between costs of hydro power and fossil fuel power cannot be made on a B.T.U. basis, because the former is not measurable in terms of heat units. Instead, comparison is based upon over-all production costs of generating electricity, stated in terms of mills per net kilowatt hour generated. On such a basis, hydroelectric stations in Pennsylvania compare favorably with almost all coal, oil, and gas powered plants.

Production costs are available for 122 generating plants in Pennsylvania (Deasy and Griess, 1959). Of this number, 24 are very high cost plants (over 20 mills per net KWH), 36 are high cost (9 to 20 mills), 28 are medium cost (6 to 9 mills), and 34 are low cost (under 6 mills). Among the hydroelectric plants of the State, 8 of the 10 are in the low cost category, and the remaining 2 are medium cost plants. The lowest cost generating plant in the Commonwealth is that of the Safe Harbor Water Power Corp. (#111), with production costs of slightly over one-half mill per net KWH. Thus, where developed, hydroelectric sites effectively keep out or reduce the need for competing sources of energy. The effectiveness of hydro power as a deterrent to other sources of power, however, is somewhat reduced by the fact that some hydro stations operate intermittently to meet peak loads rather than full time to supply base loads. For example, in 1956, plant #64 operated only about half time; #83, #85, and

#133 only about two-thirds time; and #87 about three-quarters time. On the other hand, #100 and #111 were connected to the lines full time. Hydro plants are especially adapted to peak load use since they can be placed in operation almost instantaneously without the prior warm-up period required by steam plants.

Where hydroelectric sites do not exist in the Commonwealth the threat of competition from hydro power to other sources of energy is negligible, since present supplies of hydroelectricity are limited, the expense of developing remaining potential power sites is high, and cost of transmitting electricity over any considerable distance exceeds the cost of shipping fossil fuels in their raw state to the same sites.

SUMMARY AND RECOMMENDATIONS

This study demonstrates that types and sources of energy employed in the electric generating industry of Pennsylvania are varied, and that regional differences in energy supply are due primarily to resource and transportation factors. It further indicates that, except in the case of fuel oil and gas which possess certain unique advantages, selection of an energy type or source for use at a specific generating plant is largely determined by comparative delivered costs per unit of energy. Sufficient competitive advantage for a specific fuel type or source establishes its priority at a given plant. In case of approximately equal delivered costs for two or more types or sources of energy, any one type or source, or a combination of several types or sources, is employed at a generating plant.

On the basis of evidence presented earlier in this study, recommendations can be formulated as to courses of action that are open to the several classes of Pennsylvania fuel producers which may enable them to expand their market territory in the State and increase their share of the Commonwealth's electric generating industry fuel market. Obviously, the recommendations that are beneficial to one class of Pennsylvania fuel producers may be detrimental not only to out-of-state competitors but also to other classes of Pennsylvania fuel producers.

Several courses of action are open to Pennsylvania bituminous coal producers in an attempt to improve their market position. The first, and perhaps the most obvious, is to lower mining and processing expenses per ton. This objective conceivably may be accomplished through greater emphasis on low-cost strip mining, greater mechanization of underground mining, and the concentration of mining efforts in larger and therefore presumably more efficient mines. Such action would decrease the existing differential in mining expenses between Pennsylvania bituminous coal producers and their competitors in neighboring states. However, the value of such action probably will be negated by similar efforts on the part of West Virginia and Ohio producers.

A second course of action would be to press for removal of railroad freight rate differentials, if any, that may exist between Pennsylvania and West Virginia coal marketed in Pennsylvania, and thus increase the territory in southern and eastern portions of the Commonwealth wherein Pennsylvania-derived coal has a competitive market advantage. In other words, on Figure 14, lines A, B, and C would replace corresponding lines D, E, and F.

A third procedure open to Pennsylvania bituminous coal producers is the apparently anomalous one of requesting an increase in variable railroad transportation charges on all bituminous coal shipped into southern and eastern Pennsylvania. If granted, this increase in charges would reduce the relative significance of cheaper mining now enjoyed by West Virginia producers. The increase per ton mile, however, must be equivalent on both Pennsylvania and West Virginia coal in order to be beneficial to Pennsylvania producers. Such an increase in rates would have the effect of shifting the competitive boundary between Pennsylvania and West Virginia coal southward, i.e., on Figure 14, from line A to B to C or farther south, or from line D to E to F or farther south. Of course, an increase in variable charges for transportation of bituminous coal might work to the advantage of anthracite producers, but the ability of anthracite operators to expand their market territory much beyond its present borders is open to serious question under prevailing conditions.

A fourth possibility for Pennsylvania bituminous coal producers is to work for establishment of more stringent quotas, or a complete ban on, imports of foreign oil into the Greater Philadelphia area. However, if successful, this step would benefit West Virginia coal producers as much as, or more than, Pennsylvania producers under existing conditions.

A fifth course of action is to convince present users of fuel oil and gas in western Pennsylvania of the long term benefits to be derived from the use of low-cost bituminous-coal-derived energy, despite the necessity of installing new equipment. The high cost per KWH of generating electricity in oil- and gas-using plants (Fig. 21), many of which are located in the heart of the bituminous coal fields, is a cogent argument for conversion to bituminous coal.

There appears to be little opportunity for Pennsylvania bituminous coal producers to expand their market into the area where low cost anthracite is now entrenched (Fig. 21). Such large discrepancies in the

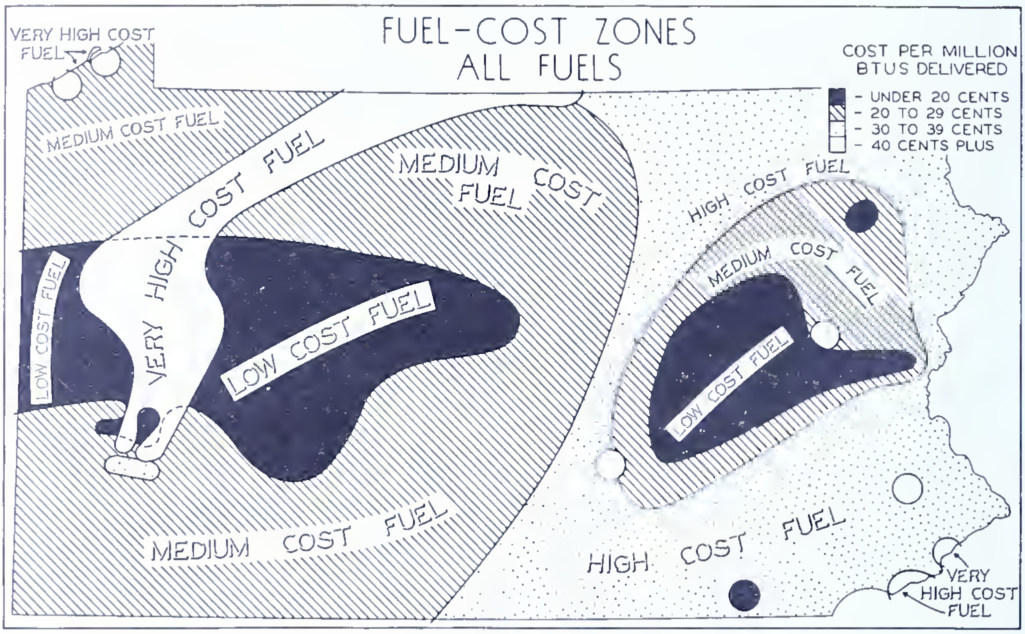

Fig. 21. Fuel-Cost Zones for Electric Generation in Pennsylvania, 1956. Figures represent delivered costs, at the generating plants, of fuels now being used. Hydro plants are not included. Source: personal communications.

delivered costs of the two fuels exist there that a shift to bituminous coal is inconceivable. Likewise, bituminous coal obviously will never be a source of primary energy in the hydroelectric plants of the State, nor can it offer competition on a KWH cost basis in areas served by such plants.

Opportunities for anthracite producers to enlarge their market territory among Pennsylvania's electric generating plants are less diverse but perhaps more promising than those available to bituminous coal producers. A major course of action is to work for reduction in the exceptionally high freight rates that currently restrict outlets for anthracite to the near vicinity of the anthracite fields. If reduced freight rates can be obtained, it might be possible for the anthracite industry to expand its market territory into southeastern Pennsylvania as far as the Greater Philadelphia area and to supply many of the electric generating plants now dependent upon Pennsylvania and West Virginia bituminous coal and imported oil.

Another possibility available to anthracite operators is to effect a complete change in their present local versus outside pricing system, raising prices drastically on local sales in what is virtually a captive market (Fig. 21) and lowering prices equivalently on outside sales in order to produce a more competitive situation in areas now excluded from the anthracite market territory. Such a pricing revision could place anthracite in a more favorable price relationship in southeastern Pennsylvania, similar to that which now exists in the Bethlehem-Easton area. Coupled with this price change could be a greatly increased publicity campaign emphasizing the benefits to be derived from use of relatively clean-burning anthracite as compared with bituminous coal. This campaign would take advantage of growing public concern over air pollution problems in highly urbanized areas such as the Greater Philadelphia territory.

Increased mechanization of underground anthracite operations offers little hope for extension of that fuel's market territory, and neither does expansion of stripping operations. Such future improvements of this nature as may be effected probably will no more than offset comparable improvements in the bituminous coal industry.

The outlook for expansion of markets for Pennsylvania-derived fuel oil and gas in the Commonwealth's electric generating industry is bleak. These fuels are non-competitive, in terms of cost, with all other types and sources of energy presently utilized in the State. At best, local fuel oil and gas producers can only hope to retain their present limited outlets, based on the high cost of changeover and the benefits they can offer in the way of cleanliness, ease of handling, and convenience of storage.

New energy patterns for the electric generating industry of Pennsylvania, in terms of costs as well as types and sources, are now in process of formulation (Deasy and Griess, 1959, p. 134-5, 147). Already, one atomic powered generating station, that at Shippingport, is in operation; and additional such plants for the State are under construction or planned. When such plants supply an appreciable percentage of the total electrical energy requirements of the Commonwealth, energy patterns will depart considerably from those of today, and the markets for Pennsylvania-produced fossil fuels will change accordingly. It behooves Pennsylvania mineral fuels producers to remain alert to such changes and meet the challenge of new conditions.

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APPENDIX

LIST OF ELECTRIC GENERATING PLANTS OF PENNSYLVANIA USED IN THIS STUDY[1]

Plant Number	*Owner*	*Name of Plant*	*Location of Plant*
1	Pittsburgh Steel Co	Monessen Plant	Monessen
2	West Penn Power Co.	Mitchell Station	Courtney
3	Duquesne Light Co.	Elrama Station	Elrama
4	(confidential)		
5	(confidential)		
6	(confidential)		
7	Westinghouse Air Brake Co.		Wilmerding
8	Westinghouse Electric Corp.	Trafford Plant	Trafford
9	Borough of Pitcairn	Municipal Light Plant	Pitcairn
10	Westinghouse Electric Corp.	East Pittsburgh Plant	Pittsburgh
11	(confidential)		
12	(confidential)		
13	Mesta Machine Co.	West Homestead Plant	West Homestead
14	Jones and Laughlin Steel Corp.	Pittsburgh Plant	Pittsburgh
15	Duquesne Brewing Co.	Duquesne Plant	Pittsburgh
16	Heppenstall Co.	Pittsburgh Plant	Pittsburgh
17	Borough of Aspinwall	Electric Light Plant	Aspinwall
18	H. J. Heinz Co.	Pittsburgh Main Plant	Pittsburgh
19	Borough of Sharpsburg	Electric Plant	Sharpsburg
20	Borough of Etna	Light Plant	Etna
21	Pennsylvania Railroad Co.	Pittsburgh Station	Pittsburgh
22	Duquesne Light Co.	Stanwix Station	Pittsburgh
23	Duquesne Light Co.	Brunot Island Station	Pittsburgh
24	Duquesne Light Co.	Reed Station	Pittsburgh
25	Lockhart Iron and Steel Co.		McKees Rocks
26	Pittsburgh Coke and Chemical Co.		Pittsburgh
27	Duquesne Light Co.	Phillips Station	South Heights
28	Jones and Laughlin Steel Corp.	Aliquippa Mill	Aliquippa

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[1] Plant numbers correspond to those shown on Figure 1.

LIST OF ELECTRIC GENERATING PLANTS OF PENNSYLVANIA USED IN THIS STUDY

Plant Number	*Owner*	*Name of Plant*	*Location of Plant*
29	Koppers Co.	Kobuta Plant	Kobuta
30	Armstrong Cork Co.	27th Street Plant	Beaver Falls
31	Pullman Standard Car Mfg. Co.	Butler Plant	Butler
32	Shenango Pottery Co.	New Castle Plant	New Castle
33	Pennsylvania Power Co.	New Castle Station	New Castle
34	Borough of Grove City	Municipal Electric Plant	Grove City
35	Cooper-Bessemer Corp.	Grove City Plant	Grove City
36	Chicago Pneumatic Tool Co.	Franklin Plant	Franklin
37	Pennsylvania Electric Co.	Oil City Station	Oil City
38	(confidential)		
39	Ravenna Arsenal	Keystone Ordnance Works	Meadville
40	Gunnison Brothers		Girard
41	Borough of Girard	Municipal Electric Plant	Girard
42	Union Iron Works	Erie Plant	Erie
43	Skinner Engine Co.	Erie Plant	Erie
44	Bucyrus-Erie Co.	Erie Plant	Erie
45	Hays Manufacturing Co.	Erie Plant	Erie
46	Hammermill Paper Co.	Erie Plant	Erie
47	Pennsylvania Electric Co.	Front Street Station	Erie
48	Pennsylvania Electric Co.	Peach Street Station	Erie
49	Pennsylvania Electric Co.	Strong Station	Erie
50	Reed Manufacturing Co.		Erie
51	General Electric Co.	Erie Plant	Erie
52	West Penn Power Co.	Connellsville Station	Connellsville
53	Alco Products	Latrobe Plant	Latrobe
54	Duquesne Light Co.	Colfax Station	Springdale
55	West Penn Power Co.	Springdale Station	Springdale
56	Aluminum Co. of America	New Kensington Plant	New Kensington
57	Borough of Tarentum	Municipal Electric Plant	Tarentum
58	Borough of Brackenridge	Electric Department	Brackenridge
59	Pennsylvania Electric Co.	Seward Station	Seward

LIST OF ELECTRIC GENERATING PLANTS OF PENNSYLVANIA USED IN THIS STUDY

Plant Number	*Owner*	*Name of Plant*	*Location of Plant*
60	Rochester and Pittsburgh Coal Co.		Homer City
61	Joseph S. Finch and Co.	Schenley Plant	Schenley
62	Borough of Ford City	Municipal Electric Plant	Ford City
63	McLain Fire Brick Co.	Clarion Plant	St. Charles
64	Pennsylvania Electric Co.	Piney Station	Clarion
65	Hyde-Murphy Co.	Ridgway Plant	Ridgway
66	West Penn Power Co.	Ridgway Station	Ridgway
67	New York and Pennsylvania Co.	Johnsonburg Plant	Johnsonburg
68	Pennsylvania Gas Co.	Roystone Station	Sheffield
69	Pennsylvania Electric Co.	Warren Station	Warren
70	Quaker State Oil Refining Corp.	Bradford Plant	Bradford
71	Enterprise Coal Mining Co.	Ponfeigh #1 Mine	Garrett
72	Berwind-White Coal Mining Co.		Windber
73	Pennsylvania Electric Co.	Saxton Station	Saxton
74	Bethlehem Steel Co.	Johnstown Plant	Johnstown
75	D. M. Bare Paper Co.	Roaring Spring Plant	Roaring Spring
76	Pennsylvania Railroad Co.	Altoona Works	Altoona
77	Pennsylvania Electric Co.	Williamsburg Station	Williamsburg
78	West Virginia Pulp and Paper Co.	Williamsburg Plant	Williamsburg
79	West Virginia Pulp and Paper Co.	Tyrone Plant	Tyrone
80	Pennsylvania Electric Co.	Philipsburg Station	Philipsburg
81	Pennsylvania Electric Co.	Shawville Station	Shawville
82	Damascus Tanning Co.		Coudersport
83	Cumberland Valley Electric Co.	Montgomery Mills Station	Mercersburg
84	Borough of Chambersburg	Electric Light Plant	Chambersburg
85	Pennsylvania Electric Co.	Raystown Station	Raystown
86	Commonwealth of Pennsylvania	Pa. Institute for Defective Delinquents	Huntingdon
87	Pennsylvania Electric Co.	Warrior Ridge Station (hydro)	Petersburg
88	Pennsylvania Electric Co.	Warrior Ridge Station (steam)	Petersburg
89	American Viscose Corp.	Lewistown Plant	Lewistown

LIST OF ELECTRIC GENERATING PLANTS OF PENNSYLVANIA USED IN THIS STUDY

Plant Number	*Owner*	*Name of Plant*	*Location of Plant*
90	Commonwealth of Pennsylvania	Pennsylvania State Univ.	University Park
91	West Penn Power Co.	Milesburg Station	Milesburg
92	Wellsboro Electric Co.		Wellsboro
93	Eberle Tanning Co.	Westfield Plant	Westfield
94	Elkland Leather Co.		Elkland
95	Troy Engine and Machine Co.	Troy Plant	Troy
96	P. H. Glatfelter Co.		Spring Grove
97	Metropolitan Edison Co.	York Station	York
98	Schmidt and Ault Paper Co.	York Plant	York
99	International Paper Co.	York Haven Plant	York Haven
100	Metropolitan Edison Co.	York Haven Station	York Haven
101	Metropolitan Edison Co.	Crawford Station	Middletown
102	Bethlehem Steel Co.	Steelton Plant	Steelton
103	Pennsylvania Power and Light Co.	Cedar Station	Harrisburg
104	Hershey Chocolate Corp.		Hershey
105	C. H. Masland and Sons		Carlisle
106	Borough of Duncannon	Light and Power Dept.	Duncannon
107	Pennsylvania Power and Light Co.	Sunbury Station	Shamokin Dam
108	Merck and Co.	Cherokee Plant	Riverside
109	Pennsylvania Power and Light Co.	Holtwood Station (steam)	Holtwood
110	Pennsylvania Power and Light Co.	Holtwood Station (hydro)	Holtwood
111	Safe Harbor Water Power Corp.		Safe Harbor
112	Borough of Ephrata	Light and Power Plant	Ephrata
113	Metropolitan Edison Co.	Titus Station	Reading
114	Colorado Fuel and Iron Corp.	E. and G. Brooke Plant #3	Birdsboro
115	Metropolitan Edison Co.	Eyler Station	West Reading
116	Bethlehem Steel Co.	Lebanon Plant	Lebanon
117	Pennsylvania Power and Light Co.	Pine Grove Station	Pine Grove
118	Atlas Powder Co.	Reynolds Plant	Tamaqua
119	Pennsylvania Power and Light Co.	Hauto Station	Hauto
120	Borough of Weatherly	Electric Department	Weatherly

LIST OF ELECTRIC GENERATING PLANTS OF PENNSYLVANIA USED IN THIS STUDY

Plant Number	*Owner*	*Name of Plant*	*Location of Plant*
121	Pennsylvania Power and Light Co.	Harwood Station	Harwood Mines
122	ACF Industries	Berwick Plant	Berwick
123	United Gas Improvement Co.	Hunlock Station	Hunlock Creek
124	M. A. Hanna Co.	Nanticoke Plant	Nanticoke
125	Glen Alden Corp.	Nanticoke Plant	Nanticoke
126	Glen Alden Corp.	Huber Plant	Huber
127	United Gas Improvement Co.	Plymouth Station	Plymouth
128	Pennsylvania Power and Light Co.	Stanton Station	Harding
129	Armour and Co.	Noxen Plant	Noxen
130	Pennsylvania Power and Light Co.	Suburban Station (high pressure)	Scranton
131	Pennsylvania Power and Light Co.	Suburban Station (low pressure)	Scranton
132	Hudson Coal Co.	Olyphant Plant	Olyphant
133	Pennsylvania Electric Co.	Oakland Station	Oakland
134	Lukens Steel Co.	Coatesville Plant	Coatesville
135	Downingtown Paper Co.		Downingtown
136	Philadelphia Electric Co.	West Chester Station	West Chester
137	Philadelphia Electric Co.	Cromby Station	Phoenixville
138	Lee Rubber and Tire Co.	Conshohocken Plant	Conshohocken
139	Philadelphia Electric Co.	Barbadoes Station	Norristown
140	Borough of Lansdale	Electric Department	Lansdale
141	Borough of Hatfield	Municipal Electric Plant	Hatfield
142	Borough of Quakertown	Municipal Electric Plant	Quakertown
143	Allentown Converting Co.		Allentown
144	Bethlehem Steel Co.	Bethlehem Plant	Bethlehem
145	Whitehall Cement Mfg. Co.		Cementon
146	Universal Atlas Cement Co.	Northampton Plant	Northampton
147	Penn-Dixie Cement Corp.	Plant #6	Bath
148	Penn-Dixie Cement Corp.	Plant #4	Upper Nazareth
149	Nazareth Cement Co.	Nazareth Plant	Nazareth
150	Lehigh Portland Cement Co.	Sandts Eddy Plant	Sandts Eddy
151	Metropolitan Edison Co.	Dock Street Station	Easton

LIST OF ELECTRIC GENERATING PLANTS OF PENNSYLVANIA USED IN THIS STUDY

Plant Number	*Owner*	*Name of Plant*	*Location of Plant*
152	Pennsylvania Power and Light Co.	Martins Creek Station	Martins Creek
153	Alpha Portland Cement Co.		Martins Creek
154	Coates Board and Carton Co.	Stroudsburg Plant	Stroudsburg
155	Pennsylvania Power and Light Co.	Wallenpaupack Station	Hawley
156	Sun Oil Co.	Marcus Hook Plant	Marcus Hook
157	Philadelphia Electric Co.	Chester Station	Chester
158	Scott Paper Co.	Chester Plant	Chester
159	Westinghouse Electric Corp	Lester Plant	Lester
160	Rohm and Haas Co.	Lennig Plant	Philadelphia
161	Collins and Aikman Corp	Philadelphia Plant B	Philadelphia
162	Pennsylvania Railroad Co.	Steam Heat Plant	Philadelphia
163	DuPont and Co.	Philadelphia Plant	Philadelphia
164	Electric Storage Battery Co.	Crescentville Plant	Philadelphia
165	Philadelphia Electric Co.	Southwark Station	Philadelphia
166	Philadelphia Electric Co.	Schuylkill Station	Philadelphia
167	Philadelphia Electric Co.	Delaware Station	Philadelphia
168	Philadelphia Electric Co.	Richmond Station	Philadelphia
169	Franklin Sugar Refinery		Philadelphia
170	Gulf Oil Corp.	Girard Point Plant	Philadelphia
171	Container Corp. of America	Philadelphia Plant	Philadelphia
172	Atlantic Refining Co.	Philadelphia Plant	Philadelphia
173	Rohm and Haas Co.	Bristol Plant	Bristol
174	(confidential)		